



JUN 18 1991

CHG 1 through CHG 24

**U.S. Department of Transportation
Federal Aviation Administration
Specification**

MODE SELECT BEACON SYSTEM (MODE S) SENSOR

LIBRARY USE ONLY

SPECIFICATION CHANGE NOTICE (SCN)

Date 10/24/89

Prepared:

1. Originator Name and Address WEC/UNISYS JOINT VENTURE ATC DEPARTMENT (MS1640) FRIENDSHIP SITE BALTIMORE, MARYLAND 21203		2. <input type="checkbox"/> Proposed <input checked="" type="checkbox"/> Approved	3. Code Ident	4. Spec. No. FAA-E-2718 AMENDMENT 2	5. Code Ident	6. SCN No. 18(24)
7. System Designation GROUND AIR	8. Related MCP. No. SEE ATTACHED	9. Contract No. DTFA01-85-C-00002	10. Contractual Activity ALG-322			
11. Configuration Item Nomenclature MODE SELECT BEACON SYSTEM (MODE S) SENSOR		12. Effectivity ALL				
This notice informs recipients that the specification identified by the number (and revision letter) shown in block 4 has been changed. The pages changed by this SCN (being those furnished herewith) carry the same date as this SCN. The pages of the page number and dates listed below in the summary of changed pages, combined with nonlisted pages of the original issue of the revision shown in block 4, constitute the current version of this specification.						
13. SCN No.	14. Pages Changed (Indicate Deletions)	S*	A*	15. Date		
	PAGES CHANGED AND TRANSMITTED HEREWITH					
18(24)	viii, 469, 470, 474, 483a, 483b, 484	X		10/24/89		
18(24)	470a, 470b, 483c, 483d		X	10/24/89		
	SUMMARY OF CHANGED PAGES					
1(7)	vi, 412	X		10/7/85		
2(8)	iii, 51, 54, 87, 88, 89, 90, 106, 197, 235, 239, 247, 248, 251, 252, 254, 255, 265, 267, 283, 289	X		10/14/85		
2(8)	89a, 89b, 255a, 255b		X	10/14/85		
3(9)	vi, 422	X		10/17/85		
4(10)	iv, v, vii, 7b, 104, 105, 215, 224, 238, 252, 259, 261, 363, 364, 365, 379, 381, 383, 386, 387, 387a, 387b, 388, 394, 397, 443	X		10/18/85		
5(11)	iv, v, 373, 374, 391, 400	X		10/24/85		
6(12)	i, vii, 4, 64, 65, 443, 445, 446, 447, 448, 449, 450, 451, 452	X		1/10/86		
7(13)	120, 431, II-3	X		1/31/86		
8(14)	12, 13, 14, 245, 287, 325, 326, 327, 332, 335, VIII-2, VIII-4, VIII-8, VIII-10	X		2/12/86		
16. Technical Concurrence <i>Byron Johnson</i>		Date 10/24/89				

* S - Indicates Supersedes Earlier Page; A - Indicates Added Page

PC27173056-1 10/85cp

FMA-E-2715 & 2716
March 24, 1953

FAA Form 1320-5 (3-66) SUPPLEMENTAL AIRWAYS SECTION

ATTACHMENT SPECIFICATION CHANGE NOTICE (SCN) CONTINUATION SHEET

Date 10/24/89
Prepared:

13. SCN No.	14. Pages Changed (Indicate Deletions)	S*	A*	15. Date
9(15)	iv, v, vi, 43, 137, 145, 355, 377, 387a, 398, 404, 422, 423, 424, VI-5a, VI-5b	X		5/3/88
10(16)	128, 137, 345, 387a, 387b, 399, 400, 403, 414, II-4, V-3, VI-5	X		5/5/88
11(17)	vi, 51, 53, 67, 68, 69, 73, 74, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 91, 92, 93, 110, 127, 173, 175, 267, 348, 349, 352, 360, 421	X		5/10/88
11(17)	86a, 86b, 93a, 93b		X	5/10/88
12(18)	108, 252, VIII-7, VIII-8	X		5/12/88
13(19)	135, 400, 450, 467c	X		5/12/88
14(20)	ii, iv, 41, 44, 70, 91, 98, 111, 112, 113, 164, 165, 166, 349, 353, 354, 374, 387a, 422, 423, III-7, III-8	X		6/10/88
15(21)	i, iv, v, viii, ix, x, xii, 18, 20, 32, 54, 55, 105, 206, 268, 269, 270, 272, 273, 274, 275, 276, 277, 278, 279, 284, 285, 287, 288, 289, 290, 294, 308, 309, 310, 329, 332, 333, 334, 335, 336, 337, 338, 339, 340, 356, 364, 365, 367, 368, 369, 379, 381, 383, 384, 386, 387, 387a, 388, 393b, 394, 397, 474, I-5, I-8, V-6, V-7, V-8, V-9, V-10, V-11, V-12, V-13, V-15	X		6/20/88
15(21)	356a, 356b, 367a, 367b		X	6/20/88
16(22)	iii, v, vi, 128, 137, 173, 184, 354, 391, 402	X		7/18/88
17(23)	v, x, xii, 51, 104, 105, 107, 107a, 107b, 206, 218, 237, 238, 239, 247, 253, 256, 272, 275, 277, 278, 280, 281, 282, 285, 286, 287, 288, 289, 295, 297, 309, 321, 333, 334, 336, 338, 339, 340, 349, 357, 387a, 387b, 388, 393a, 393b, 394, III-8, III-9, III-10, III-13, VI-5			8/15/89
17(23)	218a, 218b, 286a, 286b, 393c, 393d, 393e, 393f, 393g, 393h		X	8/15/89
18(24)	viii, 469, 470, 474, 483a, 483b, 484	X		10/24/89
18(24)	470a, 470b, 483c, 483d		X	10/24/89
RELATED NCP NO. PSCN AV AW AY		CCD NO. 9590 9589 10020		

* S - Indicates Supersedes Earlier Page; A - Indicates Added Page

PC27173056-2 11/19/85

CONTENTS

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
1.	SCOPE.....	1
1.1	Scope.....	1
1.2	Classification.....	1
1.2.1	Type.....	1
1.2.2	Capacity.....	2
1.2.3	Auxiliary equipment.....	3
2.	APPLICABLE DOCUMENTS.....	4
2.1	Applicable documents.....	4
2.2	FAA documents.....	4
2.2.1	FAA standards.....	4
2.2.2	FAA specifications.....	4
2.2.3	Other FAA documents.....	5
2.3	Other documents.....	6
2.4	Interface control documents.....	8
2.5	Availability of documents.....	8
3.	REQUIREMENTS.....	9
3.1	Equipment and services to be furnished.....	9
3.1.1	Contractor furnished.....	9
3.1.2	Government furnished.....	10
3.2	Not used.....	10
3.3	Sensor requirements.....	11
3.3.1	ATC system compatibility.....	11
3.3.2	Performance requirements.....	11
3.3.2.1	Surveillance.....	11
3.3.2.2	Data link.....	11
3.3.2.3	Continuity.....	11
3.3.2.4	Not used.....	11
3.3.2.5	Capacity.....	12
3.3.2.6	Data delays.....	15
3.3.2.7	General accuracy requirements.....	15
3.3.2.8	Accuracy values.....	16
3.3.2.9	RF link reliability.....	17
3.3.2.10	Sensor reliability.....	17
3.3.2.11	Detection and false alarm performance.....	17
3.3.3	Interfaces.....	18
3.3.3.1	Antennas.....	18
3.3.3.2	Primary radar.....	18
3.3.3.3	NAS facilities.....	18
3.3.3.4	Not used.....	18
3.3.3.5	Sensor-to-programming support facility.....	19

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.3.4	Sensor functions.....	19
3.3.4.1	Channel management.....	19
3.3.4.2	Transmitter/modulator unit.....	22
3.3.4.3	Multichannel receiver.....	23
3.3.4.4	Mode S reply processing.....	24
3.3.4.5	ATCRBS reply processing.....	25
3.3.4.6	Surveillance processing.....	27
3.3.4.7	Data link processing.....	28
3.3.4.8	Network management.....	29
3.3.4.9	(Not used.).....	32
3.3.4.10	Performance monitoring.....	33
3.3.4.11	Sensor calibration.....	33
3.3.4.12	Sensor start-up.....	33
3.3.4.13	System timing.....	34
3.3.4.14	Test target generator.....	34
3.4	Functional requirements of the sensor.....	34
3.4.1	Channel management.....	37
3.4.1.1	Overview.....	37
3.4.1.2	Channel control.....	41
3.4.1.3	Transaction preparation.....	50
3.4.1.4	Target list update.....	66
3.4.1.5	Roll-call scheduling.....	74
3.4.1.6	Transaction update.....	95
3.4.2	Transmitter/modulator.....	111
3.4.2.1	Interfaces.....	111
3.4.2.2	Modulator unit.....	113
3.4.2.3	Transmitters.....	114
3.4.2.4	Transmit/receive isolation.....	119
3.4.2.5	Transmitter protection.....	119
3.4.2.6	Sum Difference and omni-directional couplers.....	119
3.4.3	Multichannel receiver.....	121
3.4.3.1	General description.....	125
3.4.3.2	Overall receiver requirements.....	126
3.4.3.3	Front end.....	130
3.4.3.4	IF/Video processor.....	131
3.4.3.5	Auxiliary video output channel.....	136
3.4.4	Mode S reply processing.....	139
3.4.4.1	Major subunits of the Mode S processor.....	139
3.4.4.2	Video digitizer.....	141
3.4.4.3	Preamble detector.....	146
3.4.4.4	Message bit processor.....	146
3.4.4.5	Monopulse processor.....	147
3.4.4.6	Message decoding.....	149
3.4.4.7	Antenna azimuth-range-timing unit (AARTU).....	162
3.4.4.8	Information transfer to and from the Mode S processor.....	164

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.4.5	ATCRBS reply and reply-to-reply correlation processing	167
3.4.5.1	Major subunits of the ATCRBS processor	167
3.4.5.2	Video digitizer	167
3.4.5.3	ATCRBS reply processor	172
3.4.5.4	Antenna azimuth-range-timing unit (AARTU)	182
3.4.5.5	Reply processor/correlator data transfer	184
3.4.5.6	Reply correlation	185
3.4.5.7	Target report output	194
3.4.5.8	Beacon strobe generation	194
3.4.6	Surveillance processing	197
3.4.6.1	Overview	197
3.4.6.2	Surveillance file	203
3.4.6.3	Input preprocessing	208
3.4.6.4	ATCRBS target-to-track correlation	213
3.4.6.5	ATCRBS track initiation	234
3.4.6.6	ATCRBS track update	237
3.4.6.7	ATCRBS fruit rejection	242
3.4.6.8	Mode S position measurement selection	243
3.4.6.9	Mode S track initiation	247
3.4.6.10	Mode S track update	250
3.4.6.11	Mode S and ATCRBS track data message processing	258
3.4.6.12	Radar/beacon correlation	259
3.4.6.13	False target zone and image tests	262
3.4.6.14	Surveillance data dissemination and formatting	267
3.4.7	Data line processing	271
3.4.7.1	Introduction	271
3.4.7.2	Input message processor	271
3.4.7.3	Output message processor	280
3.4.8	Network management	291
3.4.8.1	Purpose and overview	291
3.4.8.2	Network management lists	293
3.4.8.3	Coverage map	296
3.4.8.4	Network control messages	308
3.4.8.5	Routine network management tasks	311
3.4.8.6	Handling of surveillance boundary crossings	317
3.4.8.7	Handling of target track status transitions	319
3.4.8.8	Adjacent sensor inputs	322
3.4.8.9	User inputs	327
3.4.8.10	Handling of network control output messages	327
3.4.8.11	Intersensor track data exchange for ATCRBS	327
3.4.8.12	Message routing management	332
3.4.9	(Not used.)	341

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.4.10	Performance monitoring	343
3.4.10.1	Description	343
3.4.10.2	Hardware monitors	343
3.4.10.3	Performance monitor software	347
3.4.10.4	Performance monitor display	357
3.4.10.5	Control of system configuration for maintenance	363
3.4.10.6	Remote maintenance monitoring system (RMS)	363
3.4.11	Sensor calibration	367
3.4.11.1	Purpose	367
3.4.11.2	The off-boresight look-up table	367
3.4.11.3	Calibration procedure	367
3.4.11.4	Range calibration	369
3.4.12	Sensor start-up	371
3.4.12.1	Definition and purpose	371
3.4.12.2	Real-time clock synchronization	371
3.4.12.3	Program loading	371
3.4.12.4	Site adaptation modification	371
3.4.12.5	Not used	371
3.4.12.6	Performance monitoring check	371
3.4.12.7	Initial acquisition of Mode S aircraft	372
3.4.12.8	Normal operation with Mode S lockout	372
3.4.13	System timing	373
3.4.13.1	Description	373
3.4.13.2	Time-of-year (TOY) clock	373
3.4.13.3	Station time clock	373
3.4.13.4	Performance monitoring function inputs	374
3.4.13.5	Data transfer to channel management	374
3.4.13.6	Standby power	374
3.4.13.7	Start and restart procedure	374
3.4.14	Test target generator	375
3.4.14.1	Reply data channels	375
3.4.14.2	Reply data memory	375
3.4.14.3	Processor control	375
3.4.14.4	TTG data input	377
3.4.14.5	Antenna ACP and ARP simulation	377
3.4.14.6	Operator's control function	377
3.4.14.7	Modes of operation	377
3.4.14.8	TTG operational use	377
3.4.14.9	Functions tested	378
3.5	Interface requirements	379
3.5.1	Antennas	379
3.5.1.1	Azimuth pulse generator modifications	379
3.5.2	Radar (primary) interface	380
3.5.2.1	Common digitizer interfaces	380
3.5.2.2	CD-2 interface	381
3.5.2.3	Not used	383

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.5.2.4	Airport surveillance radar (ASR-9)	383
3.5.2.5	Not used	384
3.5.3	NAS facilities interfaces and communications link	386
3.5.3.1	ATC communication link	386
3.5.3.2	Non-ATC communications link	387
3.5.3.3	Surveillance link	387
3.5.4	Not used	387
3.5.5	Sensor-to-support facilities communications link	387
3.5.6	ARIES interface	387a
3.5.6.1	ARIES RF interface	387a
3.5.6.2	ARIES digital interface	387a
3.5.7	Remote maintenance monitoring system (RMMS)	387a
3.5.7.1	Mode S RMS to MPS interface	387a
3.5.7.2	Mode S RMS to local terminal interface	387b
3.5.8	ELA-STD-RS-ABC Interfaces	387b
3.5.8.1	Modem interface	387b
3.5.8.2	Processor interface	388
3.5.9	Special operation with ASR-9 interface	388
3.6	Sensor program adaptation	389
3.6.1	Master program	389
3.6.2	Sensor site program	389
3.6.3	Program adaptation parameters	389
3.6.4	Sensor site adaptation	390
3.7	Sensor architecture	391
3.7.1	Sensor front end	391
3.7.2	Computer subsystem	391
3.7.2.1	General subsystem structure	391
3.7.2.2	Task assignment	393
3.7.2.3	Requirements	393
3.7.2.4	Computer subsystem control	393a
3.7.3	Calibration and performance monitoring equipment	393a
3.7.4	Communications subsystem	393a
3.7.5	Mode S sensor control	393b
3.7.6	Mode S remote control	393f
3.7.7	Mode S/ASR-9 backup mode	394
3.7.8	Mode S/ATC-BI back-up mode	394
3.7.9	Not used	394
3.8	Data extraction	395
3.8.1	Data categories	395
3.8.1.1	Interrogation and reply data	396
3.8.1.2	Surveillance data	396
3.8.1.3	Performance monitoring data	396
3.8.1.4	Intersite data	396
3.8.1.5	Scan data	396
3.8.1.6	System diagnostic data	396
3.8.1.7	Conditions of extraction	397
3.8.2	Data reduction	397
3.8.2.1	Quick-look data processing	397
3.8.2.2	Extended data processing	397
3.8.3	Extraction equipment	397
3.8.3.1	Computer subsystem control and data extraction peripheral equipment	398

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.8.4	Sensor programming support facility	398
3.9	Reliability and maintainability	399
3.9.1	Definitions applicable to reliability and maintainability	399
3.9.1.1	Maintenance Concept	400
3.9.2	Sensor reliability and maintainability requirements	401
3.9.2.1	Reliability	401
3.9.2.2	Maintainability	402
3.9.2.3	Exclusions from 3.9.2.1 and 3.9.2.2	403
3.9.3	Reliability program	403
3.9.3.1	Reliability program plan	403
3.9.3.2	Control of subcontractors and suppliers	403
3.9.3.3	Reliability program tasks	403
3.9.4	Maintainability program	407
3.9.4.1	Maintainability program plan	407
3.9.4.2	Not used	407
3.9.4.3	Maintainability program tasks	407
3.10	Maintenance and test equipment	411
3.10.1	Standard maintenance equipment	411
3.10.2	Mode S specialized support equipment	412
3.10.2.1	Circuit card assembly test set	412
3.10.2.2	Plug-in assembly extenders	412
3.10.2.3	Special tools and ancillary items	412
3.10.2.4	Other equipment	412
3.11	General design requirements	413
3.11.1	Electrical design requirements	413
3.11.1.1	Operational electrical conditions	413
3.11.1.2	Operating environment	414
3.11.1.3	Nonoperating environment	415
3.11.1.4	Input AC line controls	415
3.11.1.5	Power supplies	415
3.11.1.6	Cabinet supply wiring	416
3.11.1.7	Batteries	416
3.11.1.8	Relays	416
3.11.1.9	Electron tubes	417
3.11.1.10	Electronic design	417
3.11.1.11	Grounding requirements	417
3.11.1.12	Conducted and radiated electromagnetic interference	417
3.11.2	Mechanical design requirements	417
3.11.2.1	Construction and packaging	418
3.11.2.2	Personnel safety and environment	420
3.11.2.3	Convenience outlets	421
3.11.2.4	Cabinet ventilation and cooling	421
3.11.2.5	Overheat condition detection and reporting	421
3.11.2.6	Finishes	422
3.11.2.7	Dissimilar metals	422
3.11.2.8	Mechanical design of electronic components	422
3.11.2.9	Cable entry and exit locations	426

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.11.2.10	Reference designations and marking	426
3.11.2.11	Moisture pockets	426
3.11.2.12	Other requirements	426
3.12	Computer programs	427
3.12.1	Functional programs	428
3.12.2	Support programs	428
3.12.3	Software design and development	428
3.12.3.1	Development planning	428
3.12.3.2	Software design	428
3.12.3.3	Software implementation	431
3.12.3.4	Commonality	433
3.12.3.5	Software reliability	434
3.12.3.6	Software maintainability	434
3.13	Documentation	435
3.13.1	System documentation	436
3.13.1.1	Program management status reports (PMSR's).....	436
3.13.1.2	System design data	437
3.13.1.3	System qualification & acceptance test plans.....	441
3.13.1.4	Not used.....	442
3.13.1.5	Not used.....	442
3.13.1.6	Site preparation reports	442
3.13.1.7	Installation documents	443
3.13.1.8	As-built installation drawings	443
3.13.1.9	Interface control documents	443
3.13.1.10	NAS integration test procedures	443
3.13.1.11	Electromagnetic interference control plan	444
3.13.1.12	Quality control system plan	444
3.13.2	Hardware documentation	444
3.13.2.1	Reliability and maintainability documentation	444
3.13.2.2	Equipment instruction books	445
3.13.2.3	Drawings and technical memoranda	450
3.13.2.4	Provisioning technical documentation	451
3.13.2.5	Operator's manuals.....	451
3.13.3	Software documentation	451
3.13.3.1	Version description document (VDD).....	451
3.13.3.2	Software user's manual.....	451
3.13.3.3	Software maintenance manual.....	452
3.13.3.4	Diagnostics manual.....	452
3.13.4	Configuration management plan.....	452
3.13.5	Life cycle cost documentation.....	454
3.13.5.1	Life cycle cost model description.....	454
3.13.5.2	Life cycle cost analysis reports.....	454
3.13.5.3	Life cycle cost estimation reports.....	454

-vii-

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>	
3.14	Spare parts	455	
# 3.14.1	CMF spares	455	#
3.14.2	Depot spares	455	
# 3.14.3	Sensor support facility spares.....	455a	#
3.15	Installation and checkout	457	
3.15.1	Air traffic control operating constraints	457	
3.15.2	Equipment and services to be furnished	457	
3.15.2.1	Equipment and services to be provided by the contractor	457	
3.15.2.2	Government furnished equipment (GFE) and services ...	458	
3.15.3	Documentation	460	
3.15.3.1	Installation documents	460	
3.15.3.2	Test documentation	462	
3.15.4	Sensor installation	465	
3.15.4.1	Mode S equipment installation	465	
3.15.4.2	Power connection	465	
3.15.4.3	Installation of conduit, ductwork, and wiring	465	
3.15.4.4	Integration into the NAS	465	
3.15.5	Personnel	465	
3.15.6	Test equipment and tools	466	
3.15.7	Spare parts	466	
3.15.8	Cleaning	466	
3.15.8.1	Interior	466	
3.15.8.2	Exterior	466	
3.15.9	Facility commissioning	466	
3.15.10	On-site acceptance test	467	

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
3.16	Configuration and data management.....	467b
3.16.1	Configuration management (CM).....	467b
3.16.1.1	Functional configuration identification (FCI).....	467b
3.16.1.2	Allocated configuration identification (ACI).....	467b
3.16.1.3	Product configuration identification (PCI).....	467b
3.16.1.4	Configuration item development records (CIDRs).....	467c
3.16.1.5	Interface control.....	467c
3.16.1.6	Item identification.....	467c
3.16.2	Configuration control.....	467c
3.16.2.1	Specification maintenance.....	467c
3.16.2.2	Engineering change requests (ECR's).....	467c
3.16.2.3	Request for deviations or waivers (RFD's/RFW's).....	467d
3.16.2.4	Engineering release records.....	467d
3.16.3	Configuration status accounting.....	467d
3.16.4	Configuration audits.....	467d
3.17	Life cycle cost.....	467d
3.17.1	Life cycle cost model.....	467d
3.17.2	Life cycle cost analysis.....	467d
3.17.3	Life cycle cost estimation.....	468

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
4.	QUALITY ASSURANCE PROVISIONS.....	469
4.1	General.....	469
4.1.1	Testing requirements.....	470
4.1.1.1	Inspection and testing pf sensors.....	470
4.1.1.2	Inspection and testing of other sensors.....	470a
4.1.2	Recording of test data.....	470a
4.1.3	Test direction.....	470a
4.1.4	Failure recording and reporting.....	470b
4.2	Test conditions.....	471
4.3	Tests and inspections.....	471
4.3.1	Quality control.....	471
4.3.1.1	Incoming inspection.....	471
4.3.1.2	First article inspection.....	471
4.3.2	Contractor's preliminary tests.....	472
4.3.3	Design qualification tests.....	472
4.3.3.1	General characteristics tests.....	472
4.3.3.2	Environmental tests.....	472
4.3.3.3	Reliability test and demonstration.....	473
4.3.3.4	Maintainability test.....	474
4.3.3.5	Sensor design qualification test.....	474
4.3.4	Type tests.....	481
4.3.4.1	Performance type test.....	481
4.3.4.2	Production reliability verification type test.....	481
4.3.4.3	Temperature and humidity type tests.....	482
4.3.5	Production tests.....	482
4.3.6	Availability calculation.....	483
4.3.7	On-site acceptance test.....	483
4.3.8	Integration tests.....	483a
4.3.8.1	ASR-9 interface tests.....	483a
4.3.8.2	ARTS IIA interface tests.....	483c
4.4	Software test requirements.....	483c
4.4.1	Informal software testing.....	483c
4.4.1.1	Module (unit) tests.....	483d
4.4.1.2	Functional string test.....	483d
4.4.2	Formal software testing.....	483d
4.4.2.1	Preliminary qualification testing.....	483d
4.4.2.2	Formal qualification testing.....	483d
4.4.2.3	Hardware-software integration testing (HSIT).....	483d
4.5	Sensor hardware software integration testing (sensor HSIT).....	484

CONTENTS (CONTINUED)

<u>Paragraph</u>	<u>Title</u>	<u>Page</u>
5.	PREPARATION FOR DELIVERY.....	485
5.1	System and equipment deliveries.....	485
5.2	Depot spare parts deliveries.....	485
5.3	Documentation.....	485
6.	NOTES.....	485

APPENDICES

I.	LIST OF ABBREVIATIONS AND ACRONYMS.....	I-1
II.	SUPPORT FACILITIES.....	II-1
III.	REQUIREMENTS FOR OPERATION WITH BACK-TO-BACK ANTENNA.....	III-1
IV.	REQUIREMENTS FOR USE WITH TERMINAL RADAR SYSTEMS.....	IV-1
V.	MODE SELECT REQUIREMENTS FOR JOINT-USE SITES.....	V-1
VI.	REQUIREMENTS FOR VIDEO RECONSTITUTOR, BACK-UP (ATC-BI) MODE, AND SURVEILLANCE DATA SELECTOR.....	VI-1
VI-A.	REQUIREMENTS FOR BEACON DECODER TO BE USED WITH THE MODE S SENSOR VIDEO RECONSTITUTOR.....	VI-A-1
VII.	VIDEO DELAY UNIT.....	VII-1
VIII.	CALIBRATION PERFORMANCE MONITOR EQUIPMENT (CPME).....	VIII-1
IX.	AIRCRAFT REPLY AND INTERFERENCE ENVIRONMENT SIMULATOR (ARIES).....	IX-1
X.	FAA 80'S MAINTENANCE CONCEPT.....	X-1
XI.	SENSOR CONFIGURATIONS FOR INITIAL IMPLEMENTATION.....	XI-1

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
3.3.4-1	Mode S sensor block diagram.....	20
3.4.1-1	Channel management block diagram.....	40
3.4.2-1	Control block content.....	112
3.4.2-2	Uplink encoder.....	115
3.4.2-3	RF system block diagram.....	116
3.4.3-1	Receiver front-end block diagram.....	122
3.4.3-2	IF monopulse processor and auxiliary video output channel block diagram.....	123
3.4.3-3	Video quantizer.....	124
3.4.4-1	Functional block diagram of Mode S processing subsystem.....	140
3.4.4-2	Mode S video digitizer.....	142
3.4.4-3	Data block sample timing relative to preamble.....	144
3.4.4-4	Initial conditions for error detection.....	150
3.4.4-5(a)	Final conditions of error detection logic for L = 1 (112 bit reply).....	152
3.4.4-5(b)	Final conditions of error detection logic for L = 0 (56 bit reply).....	153
3.4.4-6(a)	Initialization of error pattern location logic for L = 1 (112 bit reply).....	155
3.4.4-6(b)	Initialization of error pattern location logic for L = 0 (56 bit reply).....	156
3.4.4-7	Generation of correction enable bit.....	158
3.4.4-8	Correction of decision sequence.....	159
3.4.4-9(a)	Final state of error correction function for L = 1 if m was set.....	160
3.4.4-9(b)	Final state of error correction function for L = 0 if m was set.....	161
3.4.4-10	Mode S processor control and data block content.....	165
3.4.5-1	ATCRBS processor functional block diagram.....	168
3.4.5-2	ATCRBS video digitizer.....	169
3.4.5-3	ATCRBS reply processor functional block diagram.....	174
3.4.5-4	Example of phantom bracket pulse pair.....	176
3.4.5-5	ATCRBS target report data block contents.....	195
3.4.6-1	Surveillance processing for ATCRBS.....	199
3.4.6-2	Surveillance processing for Mode S.....	202
3.4.6-3	Example of resolution matrix.....	226
3.4.6-4	Position and orientation of reflecting surface.....	263
3.4.6-5	Computation of real aircraft position.....	264
3.4.8-1	Network management tasks - block diagram.....	292
3.4.8-2	Grid structure.....	299
3.4.8-3	Status transition diagram.....	320
3.4.8-4	Coordinate transformation.....	326
3.4.8-5	Context of message routing function.....	333
3.4.10-1	On-line transmitter/receiver monitor.....	344
3.4.14-1	Test target generator, system interconnection.....	376

ILLUSTRATIONS (CONTINUED)

<u>Figure</u>		<u>Page No.</u>
3.5-1	Not used.....	381
3.5-2	Not used.....	382
3.5-3	Not used.....	382
3.5-4	Not used.....	383
3.5-5	Not used.....	385
3.7-1	Mode S sensor system architecture.....	392

ILLUSTRATIONS IN APPENDICES

III-1	Functional block diagram of the front end of a Mode S en-route sensor.....	III-4
III-2	Back-to-back coverage wedges.....	III-5
III-3	On-line transmitter/receiver monitor block diagram for the back-to-back sensor.....	III-11
III-4	Mode S back-to-back sensor configuration for system reliability.....	III-14
IV-1	Mode S/primary radar functional operation.....	IV-4
IV-2	Radar tracking tasks and interfaces.....	IV-7
IV-3	Radar surveillance file fields.....	IV-9
V-1	Mode S joint use enroute sensor.....	V-4
VI-1	Video Reconstitutor and interface block diagram.....	VI-4
VI-A-1	Mode S/ARTS IIIA configuration.....	VI-A-3
VI-A-2	Code select panel.....	VI-A-5
VI-A-3	Display control panel.....	VI-A-7
VI-A-4	Display output symbology.....	VI-A-9
VII-1	Video delay and interface block diagram.....	VII-3
VIII-1	Power level received from CPME.....	VIII-10
IX-1	ARIES system.....	IX-4
XI-1	Initial ARTS-III/Mode S Sensor Interface.....	XI-4
XI-2	Initial CD-2/Mode S Interface - Without CD-2 Modification.....	XI-5
XI-3	Initial CD-2/Mode S Interface - With CD-2 Modification.....	XI-6

TABLES

<u>Table</u>	<u>Page</u>
3.3.2.5-1 Capacity requirements.....	13
3.4.1-1 Fields of Mode S interrogation message, MESS.....	87
3.4.4-1 Mode S bit processing decision rules.....	148
3.4.5-1 Clear pulse processing decision rules.....	181
3.4.5-2 Overlapped pulse processing decision rules.....	183
3.4.6-1 Surveillance file.....	204
3.4.6-2 Altitude representations.....	211
3.4.6-3 Altitude association cases.....	216
3.4.6-4(a) Association table for zones 1 and 2.....	220
3.4.6-4(b) Association table for zone 3.....	220
3.4.6-5 Altitude update cases.....	240
3.4.6-6 Values of β vs track firmness, f.....	251
3.4.6-7 Track firmness transition rules.....	252
3.4.8-1 Summary table.....	297
3.4.8-2 Definition of components of the coverage map.....	301
3.4.8-3 Calculation of cell index I.....	304
3.4.8-4(a) Data block formats for network control messages.....	309
3.4.8-5 ATCRBS network management lists.....	330
3.4.10-1(a) Sensor status declaration decision table.....	358

TABLES IN APPENDICES

VIII-1	CPME replies to all-call interrogations.....	VIII-6
--------	--	--------

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
SPECIFICATION
MODE SELECT BEACON SYSTEM SENSOR

1. SCOPE

1.1 Scope.- This specification contains the requirements for the design, fabrication, quality assurance, and preparation for delivery of a Mode Select (Mode S) Beacon System Sensor. This sensor singly and in cooperation with other sensors, will provide surveillance of ATCRBS- and Mode S-equipped aircraft and two-way digital communications with aircraft equipped with Mode S transponders. Surveillance data and data-link services will be provided via suitable land links to the NAS Terminal and En Route control and display facilities, and to flight services automation systems.

1.2 Classification.- Three types of Mode S sensors of varying capacity and configuration are covered by this specification.

1.2.1 Type.- Mode S sensors differing in these basic characteristics are covered by this specification:

Type I - Terminal sensor.- This type includes provisions for interfacing with an airport surveillance radar (ASR) antenna having a single face, a five channel (3 beacon, 2 radar) rotary joint, and an RF feed suitable for beacon interrogation and reception. Software for this type of Mode S sensor is capable of managing beacon interrogations and replies from a single antenna face.

Type IIA - Single face en route sensor.- This type includes provisions for interfacing with air route surveillance radar (ARSR) antenna having a single face, a rotary joint with 3 beacon plus radar channels, and an RF feed suitable for beacon interrogation and reception. Software for this type of Mode S sensor is capable of managing beacon interrogations and replies from a single antenna face.

Type IIB - Back-to-back en route sensor.- This type includes provisions for interfacing with an air route surveillance radar (ARSR) antenna having back-to-back beacon antenna faces (requiring 6 beacon plus radar channels in the rotary joint), and computer subsystem controlled switching between two oppositely pointing beacon antenna faces. Software for this type of Mode S is capable of handling beacon interrogations and replies from the two back-to-back beacon antenna faces.

Type IIIA - Single face en route joint use sensor.- This type includes provisions for interfacing with an air route surveillance radar antenna having a single face beacon antenna (requiring 3 beacon plus radar channels) shared by the FAA and the Air Defense Command (ADCOM). Software for this sensor type is capable of handling beacon interrogations and replies from a single antenna face.

Type IIIB - Back-to-back en route joint use sensor.- This type includes provisions for interfacing with an air route surveillance radar antenna having back-to-back beacon antenna faces shared by the FAA and the Air Defense Command (ADCOM). Further, this sensor type is capable of transmitting Mode 4 interrogations from its front face while Mode S interrogations are being transmitted from the rear face (requiring 6 beacon plus radar channels in the rotary joint). Software for this sensor type is capable of handling beacon interrogations and replies from the oppositely pointing antenna faces, and switching between mode types upon command.

1.2.2 Capacity.- The traffic handling capacity of a Mode S sensor of any type shall be denoted Class I, Class II, or Class III as specified in 3.3.2.5. The sensor class shall be as specified in the contract schedule.

1.2.3 Auxiliary equipment.- A Mode S sensor shall be able to operate in conjunction with auxiliary equipment as listed below. Requirements for each equipment and its interface with the Mode S sensor are specified in appendices and subsections of this specification. The number of each of these equipment items to be furnished shall be as specified in the contract schedule:

<u>Auxiliary Equipment</u>	<u>Requirement</u>
(a) Performance monitor display	3.4.10.4
(b) Programming or Mode S support facility	Appendix II
(c) Back-to-back antenna	Appendix III
(d) Terminal radar systems	Appendix IV
(e) Joint-use sites	Appendix V
(f) Video reconstitutor and surveillance data selector	Appendix VI
(g) Beacon decoder	Appendix VI-A
(h) Video delay unit	Appendix VII
(i) Calibration and performance monitor equipment	Appendix VIII
(j) Aircraft reply and interference environment simulator	Appendix IX

This space intentionally unused.

2. APPLICABLE DOCUMENTS

2.1 Applicable documents.- The following specifications and standards, of the issues specified in the request for proposal, form a part of this specification. This specification shall have precedence over all specifications, standards, documents, etc., listed or referenced herein, in the event of conflict.

2.2 FAA documents.

2.2.1 FAA standards.-

FAA-STD-002	Engineering Drawings
FAA-STD-005	Preparation of Specifications
FAA-STD-007	Program Evaluation Review Technique (PERT) Procedures for Contract Use
FAA-STD-010	Graphic Symbols for Digital Logic Equipment
FAA-STD-016	Quality Control System Requirements
FAA-STD-018	Software Quality Assurance Standards
FAA-STD-019	Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities
FAA-STD-020	Transient Protection, Grounding, Bonding and Shielding Requirements for Equipment
FAA-STD-021	Configuration Management

2.2.2 FAA specifications.-

FAA-C-1217	Electrical Work, Interior
FAA-D-2494	Technical Instruction Book Manuscript: Electronic, Electrical, and Mechanical Equipment, Requirements for Preparation of Manuscript and Production of Books
FAA-E-2217	Digital Data Communications System
FAA-E-2660	ATCRBS Open Array Antenna (5 ft.)
FAA-E-2679	Common Digitizer-2 (CD-2)

FAA-E-2698	Maintenance Processor Subsystem
FAA-E-2704	Airport Surveillance Radar (ASR-9), Appendix III, MTD/Mode S Interface
FAA-G-1210	Provisioning Technical Documentation
FAA-G-1375	Spare Parts-Peculiar for Electronic, Electrical, and Mechanical Equipment
FAA-G-2100	Electronic Equipment, General Requirements
FAA-ER-240-35a	Antenna Group, Enroute DABS/ATCRBS, Array
FAA-ER-240-35b	Antenna Group, Enroute Beacon, Array

2.2.3 Other FAA documents.-

FAA-RD-76-219	DABS Monopulse Summary
FAA-RD-78-96	The Aircraft Reply and Interference Environment Simulator (ARIES)
FAA-RD-80-14	DABS/ATC Facility Surveillance and Communication Message Formats
FAA-RD-81-39	A Los Angeles Basin 1100 Aircraft Traffic Model
DOT/FAA/RD-82/37	Generation of the Mode Select Sensor Coverage Map
DOT/FAA/FM-83/8	Mode S Functional Description
DOT/FAA/RD-82/58	Mode S Installation and Siting Criteria
DOT/FAA/FM-83/37	Department of Transportation, Federal Aviation Administration Software Acquisition Documentation Requirements for MODE Select Beacon System (Mode S) Sensor.
FAA Order 1010.51A	U.S. National Standard for the IFF Mark X (SIF) Air Traffic Control Radar Beacon System (ATCRBS) Characteristics
FAA Order 1320.33	Equipment Modification and Facility Instruction Directives

FAA Order AF 6000.10

Airways Facilities Service Maintenance Program

FAA Order 6032.1

Modification to Ground Facilities, Systems, and Equipment in the National Airspace System

FAA Order 6365.1A

U. S. National Standard for the Mode Select Beacon System

FAA Order 6950.19

Practices and Procedures for Lightning Protection, Grounding, Bonding and Shielding Implementation

NAS-MD-790

Interface Control Document for The Remote Maintenance Monitoring System (RMMS) (Level I ICD)

NAS-MD-791

Guidelines for the Development of Level II Interface Control Documents for Remote Maintenance Monitoring System (RMMS)

NAS-MD-792

Operational Requirements for the Remote Maintenance Monitoring System (RMMS)

FAA Drawing No. D-6048-1

ASR-4,-5,-6 Prefabricated Metal Building Typical Site Construction

2.3 Other documents.-

MIL-HDBK-217

Reliability Prediction of Electronic Equipment

MIL-HDBK-472

Maintainability Prediction

DOD-STD-100	Engineering Drawing Practices	
MIL-STD-275	Printed Wiring for Electronic Equipment	
MIL-STD-454	Standard General Requirements for Electronic Equipment	
MIL-STD-461	Electromagnetic Interference Characteristics Requirements for Equipment	
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of	
MIL-STD-470	Maintainability Program Requirements for Systems and Equipment	
MIL-STD-471	Maintainability Verification Demonstration and Evaluation	
MIL-STD-490	Specification Practices	
MIL-STD-756	Reliability Prediction	
MIL-STD-781	Reliability Tests, Exponential Distribution	
MIL-STD-785	Reliability Programs for Systems and Equipment Development and Production	
MIL-STD-881	Work Breakdown Structures for Defense Material Items	
MIL-STD-883	Test Methods and Procedures for Microelectronics	
MIL-STD-965	Parts Control Program	
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities	
MIL-STD-1521	Technical Reviews and Audits for Systems, Equipment, and Computer Programs	
DOD-D-1000	Drawing, Engineering and Associated Lists	
MIL-D-5480	Data, Engineering and Technical, Reproduction Requirements for	
MIL-E-75	Electron Tubes, Preparation for Delivery of	

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-5

-7a-

MIL-E-17555	Electronic and Electrical Equipment Accessories and Repair Parts, Packaging and Packing of
MIL-M-9868	Microfilms of Engineering Drawings, 35 MM, Requirements for
MIL-M-38510	Microcircuits, General Specification for
ANSI X3.4	Code for Information Interchange
ANSI X3.28	American National Standard, Procedures for the Use of the Communication Control Characters of American National Standard Code for Information Interchange in Specified Data Communication Links
ANSI X3.64	Additional Controls for use with American National Standard Code for Information Interchange
ANSI X3.66	National Standard for Advanced Data Communication Control Procedures (ADCCP)
ANSI Y1.1	Abbreviations for use on Drawings and in Text
ANSI Y32.14	Graphic Symbols for Logic Diagrams (Two-State Devices)
T.O. 31P4-2GPA124-2	Coder-Decoder Group, AN/GPA-124
DI-A-5239	Management Plan
DI-E-3102	Configuration Item Development Specification
DI-E-3103	Configuration Item Product Fabrication Specification
DI-E-30132	Critical Item Product Fabrication Specification
DI-T-3701	System Test Plan
DI-T-3714	Acceptance Test Procedures
DI-T-3718	Test Reports -- General
EIA RS-232	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange

-7b-

FAA-E-2716 & AMEND.-2
SCN-4 (Change 10)

EIA-STD-RS-ABC

General Purpose 25 Position Interface for
Data Terminal Equipment and Data Circuit
Terminating Equipment Employing Serial
Binary Data Interchange, Draft dated
March 1985.

FED-STD-595

Colors

	FIPS PUB 3	Recorded Magnetic Tape for Information Exchange (800 CPI, NRZI)	
#	FIPS PUB 17	Character Structure and Character Parity Sense for Serial-By-Bit Data Communication in the Code for Information Interchange	#
#	FIPS PUB 25	Recorded Magnetic Tape for Information Exchange (1600 CPI, phase encoded)	#
	NFPA-70	National Electrical Code	
	NFPA-78	Lightning Protection Code, ANSI C5.1	
#	TR-75-22	Rome Air Development Center (RADC) Technical Report, Non-Electrical Reliability Notebook	#

2.4 Interface Control Documents.

ASR-9 C&I Processor to Mode S Sensor

Mode S Sensor to ASR-9 Surveillance Processor

Mode S Sensor/ATCRBS to ASR-9 Surveillance Processor Beacon Target Detector

2.5 Availability of documents.- Copies of this specification and other applicable FAA specifications, standards and drawings may be obtained from the Contracting Officer in the Federal Aviation Administration Office issuing the invitation for bids or request for proposals. Requests should fully identify material desired, i.e., specification, standard, amendment, and drawing numbers and dates. Requests should cite the invitation for bids, request for proposals, or the contract involved or other use to be made of the requested material.

Single copies of Military specifications and standards may be obtained from Federal Aviation Administration, Washington, D.C. 20591, ATTN: Contracting Officer. Requests should cite the invitation for bids, request for proposals, or contract for which the material is needed. Mail requests, if found acceptable, will be forwarded to a Military supply depot for filling; hence, ample time should be allowed.

Copies of the Federal Information Processing Standards Publications are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20442.

Copies of the National Electrical Code may be obtained from the National Fire Protection Association, 470 Atlantic Avenue, Boston, Mass. 02201.

3. REQUIREMENTS

This specification covers a set of equipment including hardware and software which when taken together constitute a Mode S sensor. In addition to supplying the sensor hardware and software, the contractor shall, as specified herein provide appropriate documentation for the sensor.

Software provided in response to this requirement shall be modular and flexible. Changes to sensor algorithms shall be possible without severe impact on the remainder of the sensor software.

Validity checking or error correction and detection procedures shall be as specified herein. In addition, the contractor shall incorporate such other validity checking procedures in the computer programs which are in accordance with good programming practice.

3.1 Equipment and services to be furnished.

3.1.1 Contractor furnished.- The contractor shall provide all necessary manpower, services, and materials to design, fabricate, assemble, test, deliver and install the sensor hardware and associated software as specified herein. Also, the contractor shall interconnect, test, and demonstrate the ability of the system, the subsystems, and all other equipment furnished, to meet specified performance requirements. Any feature or item necessary for proper operation of the system as specified herein, shall be incorporated even though that item may not be specifically described herein. The Mode S sensor shall be provided in the quantities and at the times specified by the contract. Where required by the contract, the work to be performed shall include any modifications and checkout of existing Government Furnished Equipment (GFE) as a part of the overall contractor system checkout effort. In addition, the contractor shall provide all necessary services and material to prepare, reproduce and provide reports, computer programs and documentation as specified herein.

All equipment and services shall be delivered to the locations specified by the Government. All facilities, parts and hardware, including system/subsystem grounding plates, receptacles, connectors, cabling wiring, adapters, and outlets, except GFE specified in 3.1.2, shall be provided to enable the components of each system to be assembled and interconnected as required by this specification. The major items of equipment and services to be furnished are:

- (a) A dual channel Mode S sensor. Each channel shall consist of an interrogation subsystem, a computer subsystem, and all necessary communications and interfaces between parts of the Mode S sensor, and between the Mode S sensor and external facilities and equipment as specified herein and called out in the contract.

- (b) Any simulators, monitoring, checkout, and calibration equipment which may be specified herein and called out in the contract.
- (c) Programming support facilities as specified herein and called out in the contract.
- (d) Functional and support software.
- (e) A module and system quality assurance program for both hardware and software (4.0).
- (f) A system reliability and maintainability program (3.9).
- (g) Documentation as specified in 3.13.
- (h) Special tools and test equipment.
- (i) Spare parts, subassemblies and/or units as mutually agreed to between the contractor and the Government.
- (j) Modifications to azimuth pulse generators, as required in the contract schedule.

3.1.2 Government furnished.- The Government will provide and/or install the following hardware and services:

- (a) Data required by the contractor for each site to develop appropriate system and site adaptation parameters, and to prepare coverage map information in the form required by the sensor.
- (b) All modems, communication lines, and/or networks required by the Mode S sensor for communication with external facilities and other Mode S sensors.
- (c) ATC computer hardware and software in accordance with the ICDs.
- (d) Any special simulators, monitoring, test equipment, test tapes, and test aircraft scenarios not supplied by the contractor (3.1.1(b)) which are deemed necessary for successful completion of the project and proper operation of the sensor as mutually agreed to between the contractor and the Government.

3.2 Not Used.

3.3 Sensor requirements.

3.3.1 ATC system compatibility.- The Mode S sensor is the basic ground element of the Mode S surveillance and communication system. It must be compatible with other elements of Mode S (e.g., antennas and transponders) and with elements of the overall ATC system (e.g., NAS Terminal and En Route). To ensure this compatibility, interfaces to these and other equipments shall utilize the signal and message formats specified in the Mode S National Standard and in the appropriate Mode S interface control document (ICD).

3.3.2 Performance requirements.

3.3.2.1 Surveillance.- The Mode S sensor shall perform surveillance of all beacon-equipped aircraft within its volume of coverage. Nominal maximum operational range shall be 255 nmi, site adaptable to appropriate shorter ranges. ATCRBS-equipped aircraft shall be interrogated by means of the ATCRBS/Mode S All-Call, ATCRBS-Only or ATCRBS interrogation at a rate that produces a fixed number of interrogations in a 3 dB beamwidth. This number shall be adjustable during site adaptation, from a nominal value of 4 to a maximum number of 6, except that the maximum interrogation rate shall not exceed 150 interrogations per second. Mode S-equipped aircraft shall be acquired by means of an ATCRBS/Mode S All-Call interrogation, a Mode S Only All-Call interrogation, or by means of ground-to-ground handover. After acquisition, Mode S-equipped aircraft shall be interrogated with a unique address call. For both ATCRBS and Mode S, azimuth shall be determined by a monopulse technique. When the Mode S sensor is collocated with a primary radar, the Mode S sensor shall accept the digitized radar target declarations and correlate them with beacon (ATCRBS and Mode S) data, prior to sending the surveillance data to NAS Terminal and En Route. In addition, Mode S shall perform radar only scan-to-scan surveillance processing when interfaced to a Moving Target Detector (MTD) or Sensor Receiver and Processor (SRAP) (see Appendices).

3.3.2.2 Data link.- The Mode S sensor shall also provide a two-way digital data link for all Mode S-equipped aircraft. Messages originating on the ground, from NAS Terminal, En Route and non-ATC sources, shall be sent to the aircraft, and appropriate acknowledgment received and relayed to the sender. The Mode S sensor shall also manage the data link so that any time an aircraft wishes to initiate an air-to-ground message, that message will be read out with minimum delay. All message types are specified in the Mode S National Standard.

3.3.2.3 Continuity.- In performing its basic surveillance and communication functions, the Mode S sensor shall participate with adjacent sensors to provide a continuity of service as aircraft move from one coverage area to another. Continuity of service shall also be provided by the network of sensors in the event of certain prescribed failures, up to the limit of the combined field-of-view of the sensors remaining active after a failure.

3.3.2.4 Not Used.

3.3.2.5 Capacity.- Each Class I sensor shall be designed to handle (to provide surveillance of all aircraft and data link services to Mode S aircraft) a total of 250 aircraft, each Class II sensor to handle a total of 400 aircraft, and each Class III sensor to handle a total 700 aircraft. Each aircraft population (250, 400, 700) shall be understood to contain any mix of Mode S, ATCRBS, and primary radar targets. Each sensor shall also handle the additional non-aircraft target reports as received from a primary radar interface (3.5.2). The design shall be capable of being altered simply (by the addition or removal of computer hardware and software modules) in order to accommodate 250, 400, or 700 aircraft. The capacity requirements stated shall be achieved when six ATCRBS/All-Call intervals are provided within the $\Delta/\Sigma = -2$ to $+2$ antenna beamwidth (equivalent to four intervals within 3 dB antenna beamwidth), and the sensor antenna is rotating at a maximum of 12.5 RPM. Target overload conditions shall be handled in an orderly manner (e.g., reduction of range within which targets are processed).

3.3.2.5.1 Target bunching.- The targets will not necessarily be distributed uniformly in azimuth or range. Some areas of airspace may contain more targets than other areas. The sensors shall be designed to handle any mix of targets in the cases of azimuthal bunching shown below when subjected to the fruit environment stated in 4.3.3.5.2.5:

Case I:

- 90° Quadrant Bunching - 250 targets within a 90° quadrant
- 11.25° Sector Bunching - 50 targets within each 11.25° sector
for up to four consecutive sectors.
- 2.4° Wedge Bunching - 12 targets within a 2.4° wedge for up to
two consecutive wedges.

Case II

- 90° Quadrant Bunching --- 250 targets within a 90° quadrant
- 11.25° Sector Bunching --- 50 targets within each 11.25° sector
for up to four consecutive sectors.
- 2.4° Wedge Bunching --- 32 targets within a 2.4° wedge.

These requirements shall be met simultaneously (all target bunching within one scan) for a uniform range distribution of targets within 50 nmi from the sensor using the nominal antenna beamwidth of 2.4 degrees and a nominal scan rate of 12.5 RPM. The ATCRBS listening window to be used in demonstrating this requirement shall be not less than 2 ms. The above bunching may occur consecutively (limited to sensor capacity) and simultaneously (e.g., peak wedge within a peak sector).

3.3.2.5.2 Data link peaking.- Each sensor shall be designed to provide full data channel utilization (ground-air-ground) under any data link scenario realizable within the channel time-line. Demonstration of efficient data channel utilization by each sensor shall be accomplished by simultaneously satisfying (within one scan) the following cases of data link peaking for the target distributions specified in 3.3.2.5.1. "Interrogation", as used in the following paragraphs, is defined as an interrogation of an aircraft by the sensor and the inclusion of the corresponding reply window on the channel time-line. An all-Mode S target mix is assumed except where noted. The capacity requirements specified shall be achieved when six ATCRBS/All-Call intervals are provided within the $\Delta/\Sigma = -2$ to $+2$ antenna beamwidth (equivalent to four intervals within the 3 dB antenna beamwidth). These requirements are summarized in table 3.3.2.5-1.

TABLE 3.3.2.5-1 CAPACITY REQUIREMENTS

(a) Surveillance capacity for each scan (any mix of Mode S and ATCRBS targets):

Sensor Class	Total Surveillance	Target Bunching		
		90°	11.25°	2.4°
I	250	250	50	32
II	400	250	50	32
III	700	250	50	32

(b) Message storage capacity:

Sensor Class	Nominal Uplink Message Storage	Maximum Uplink Message Storage	Downlink Message Storage
I	1800	4800	400
II	2800	4800	600
III	2800	4800	1100

(c) Mode S Data link capacity:

Case I:

Each ELM below is a 16-Segment ELM. The final Comm-C/Comm-D transactions for the ELM's, in the 2.4° wedges, are included in the count of Comm-A/Comm-B transactions specified for the wedges. The 2.4° wedge loading shall occur for two consecutive 2.4° wedges. The 11.25° sector loading shall occur for four consecutive 11.25° sectors. The targets transmitting N Comm-B's include air-initiated Comm-B's as follows: (1); 5 in each of the 2.4° wedges, (2); 8 in each of the 11.25° sectors, (3); 32 in the 90° quadrant. The air-initiated Comm-B's shall be no more than one message per aircraft, uniformly distributed in range over the set of aircraft, specified above, in part (a) of this table.

Type of Peaking (per scan)	Number of Mode S Targets	Targets Receiving N Comm-A's Where N =				Targets Transmitting N Comm-B's Where N =				Targets Receiving Uplink ELM's	Targets Transmitting Downlink ELM's
		1	2	4	8	1	2	3	4		
2.4° Wedge	12	4	0	5	3	3	2	1	1	1	0
11.25° Sector	50	24	0	20	6	8	4	2	2	8	3
90° Quadrant	250	140	0	85	25	32	16	8	8	40	15

TABLE 3.3.2.5-1 CAPACITY REQUIREMENTS

Case II

Each ELM below is a 16-Segment ELM. The 2.4° wedge loading shall occur once. The 11.25° sector1 sector loading shall occur once and contains the 2.4° wedge when the sector and wedge overlap. The 11.25° sector2 loading shall occur for three consecutive 11.25° sectors and shall be adjacent to the sector1 sector. The targets transmitting N Comm-B's include air-initiated Comm-B's as follows: (1); 5 in the 2.4° wedge, (2); 8 in each of the 11.25° sectors, (3); 32 in the 90° quadrant. The air-initiated Comm-B's shall be no more than one message per aircraft, uniformly distributed in range over the set of aircraft, specified above, in part (a) of this table.

Type Number of of Peaking (per scan)	Targets Receiving Mode S Targets	Targets N Comm-A's Where N =				Targets Transmitting N Comm-B's Where N =				Targets Receiving Uplink ELM's	Transmitting Downlink ELM's
		1	2	4	8	1	2	3	4		
2.4° Wedge	32	0	32	0	0	14	0	0	0	0	0
11.25° Sector1	50	0	32	10	6	18	1	2	1	8	3
11.25° Sector2	50	24	0	20	6	8	4	2	2	6	3
90° Quadrant	250	116	32	75	25	42	13	8	7	40	15

3.3.2.5.2.1 Data link quadrant peaking.- Each sensor shall be able to handle the data link message capacity specified in table 3.3.2.5-1 for the 90° quadrant peaking. The sensor shall handle this loading each scan. The sensor shall handle all the cases shown in table 3.3.2.5-1.

3.3.2.5.2.2 Data link sector peaking.- Each sensor shall be able to handle the data link message capacity specified in table 3.3.2.5-1 for the 11.25° sector peaking. The sensor shall handle this loading each scan. The sensor shall handle all the cases shown in table 3.3.2.5-1.

3.3.2.5.2.3 Data link wedge peaking.- Each sensor shall be able to handle the data link message capacity specified in table 3.3.2.5-1 for the 2.4° wedge peaking. The sensor shall handle this loading each scan. The sensor shall handle all the cases shown in table 3.3.2.5-1.

-15-

3.3.2.5.3 Data link message storage.- Each sensor shall have a nominal uplink message (Comm-A or Comm-C segment) storage capacity of 1800 messages for the 250 aircraft capacity sensor, and 2800 messages for the 400 and 700 aircraft capacity sensors. This message storage capacity shall be easily expandable to a limit of 4800 messages. In addition, each sensor shall have a downlink message (Comm-B or Comm-D segment) storage capacity of 400 messages for the 250 aircraft capacity sensor, 600 for the 400 aircraft capacity sensor, and 1100 for the 700 aircraft capacity sensor. These requirements are summarized in Table 3.3.2.5-1b.

3.3.2.5.4 Transfer of remote data.- Under any load condition, each sensor shall be capable of providing remote sensor data on 15% of the tracks in the sensor's track file to two adjacent sensors. (Complete track file will be transmitted within 7 scans). Under any load condition the sensors shall be able to receive remote sensor data on 15% of the tracks in the sensor's track file from two adjacent sensors. (Complete track file will be received within 7 scans.)

3.3.2.6 Data delays.- The following data delay requirements are to be met for all capacity conditions specified in 3.3.2.5.

3.3.2.6.1 Surveillance data.- In general, all surveillance data shall be processed and available for transmission from the sensor to the ATC facilities (both correlating and noncorrelating users) no later than 3/32 of a scan period, nor sooner than 5/64 of a scan period, after their acquisition by the sensor. However, targets whose processing time exceeds the 3/32-scan limit in order to meet the correlation rules of (3.4.6.4.8, -.9, or -.10) shall be subject to the dissemination rules specified in 3.4.6.14.1.3. Each surveillance report shall be time-tagged so that accurate tracking and timing can be accomplished at the ATC facilities.

3.3.2.6.2 Communication messages.- All uplink messages shall be delayed no more than 1/16 of a scan period from time of receipt until they are processed and available for delivery to the aircraft. All downlink communication messages shall be delayed no more than 1/16 of a scan period from the time the message is received until it is available for transmission from the sensor.

3.3.2.7 General accuracy requirements.- The range and azimuth accuracy requirements specified herein apply to the combined antenna and sensor subsystem. Compliance shall be demonstrated using the general test methods described in section 4.0 of this document using stationary, controlled test transponders, and live aircraft.

Independent software offset adjustments for the mean position error (bias) values for both range and azimuth shall be provided. The mean position error values measured using either Mode S or ATCRBS reports shall be adjustable such

that the mean errors for either report type may be nulled to less than one range or azimuth unit. Operationally compatible calibration procedures, employing these capabilities, shall be developed and used as part of the accuracy tests.

Demonstration of the sensor and antenna accuracy requirements shall be accomplished using a government furnished five-foot open array antenna as described in FAA-E-2660 and FAA-ER-240-35a. The sensor hardware and software parameters which affect accuracy (e.g., ATCRBS PRF) shall be set to the nominal values specified herein for the conduct of these tests.

These accuracy requirements shall be demonstrated using both the Terminal (Type I) and En route (Type II or III) configurations. However, for the back-to-back en route configurations, specification compliance shall be demonstrated separately for each of the antenna faces. The bias difference between the two faces shall be less than one azimuth unit.

3.3.2.8 Accuracy values.- Under the test conditions specified in section 4.0 of this document the following accuracy values shall be demonstrated. These requirements apply for received power levels at least 10 dB greater than Minimum Threshold Level (MTL) as defined in 3.4.3.2.1, and for transponders meeting the characteristics specified in the Mode S National Standard.

3.3.2.8.1 Range accuracy.- The sensor-only range errors, measured using either Mode S or ATCRBS reports, shall not exceed ± 30 feet bias (including long term drift) and 25 feet rms jitter for either Mode S or ATCRBS reports.

3.3.2.8.2 Azimuth accuracy.- The long term combined sensor plus antenna azimuth accuracy, using the government furnished five-foot open array antenna, measured separately for Mode S reports, and for ATCRBS reports, shall not exceed the following values for the indicated antenna elevation angles:

Bias (Elevation angles $< 2^\circ$): within $\pm 0.033^\circ$ (exclusive of antenna wind loading but including long term drift).

Jitter (Elevation angles $< 20^\circ$): less than 0.060° , 1 σ .

Or the equivalent RMS error of 0.068° , 1 σ .

In addition to the low elevation ($< 2^\circ$) requirements stated above, the azimuth bias component as measured using Mode S reports only, will be permitted to change as a function of the elevation angle due to the GFE antenna beam widening. (The bias component change is defined as the difference between the azimuth bias component measured at elevation angles less than 2° and the bias component values measured at higher elevation angles.) The sensor and antenna reported azimuth bias component change shall not exceed the change attributable to the antenna only. The allowable limits will be established by the government from measured antenna-only data. The antenna requirements pertinent to elevation induced errors are defined in FAA-E-2660, paragraph 3.3.1.2.3 and in FAA-ER-240-35a, paragraph 3.3.1.8.

3.3.2.9 RF link reliability. - High RF link reliability both for surveillance and for two-way data link shall be achieved in part by means of two design features. Each sensor shall be capable of reinterrogation within a beam dwell time, such that in case of failure to reach an aircraft on a single call, multiple additional calls can be made before the antenna beam passes by the aircraft. The sensor shall be designed to handle the average reinterrogation rate of 10 percent, which is included in the capacity requirements. In addition, each sensor shall be capable of working in a prescribed manner with adjacent sensors, which have a common coverage volume, to provide multiple surveillance and data-link coverage.

3.3.2.10 Sensor reliability. - The sensor shall be designed for high reliability and minimum maintenance. The design requirement is for preventive maintenance no more frequently than once every 91 days, with incidence of system failure averaging no more than once in 20,000 hours.

3.3.2.11 Detection and false alarm performance. - The sensor shall achieve the following reply probability of detection (P_D) and reply probability of false alarm (P_{FA}) performance under the conditions specified:

	MODE S	ATCRBS	CONDITION
P_D	≥ 0.99	≥ 0.99	Received reply power ≥ -76 dBm referenced to the sensor rf port in the absence of signal (RF) interference.
P_{FA}	$\leq 10^{-6}$	$\leq 10^{-6}$	In any one second interval with no signal (RF) interference.

In addition, the sensor shall demonstrate the overall detection and false alarm performance specified in 4.3.3.5.5 when operating in a controlled, simulated environment.

THIS SPACE INTENTIONALLY BLANK.

3.3.3 Interfaces.

3.3.3.1 Antennas. - Each Mode S sensor shall be designed to interface and operate with minimal adjustment with several antennas. The nominal antennas for operational use are specified in 3.5.1. (Each has sum, difference, and omni channels, for monopulse angle determination and sidelobe suppression.) Rotation rates from 5 to 15 rpm (inclusive) shall be accommodated. Nominal 3 dB beamwidth shall be 2.4° .

3.3.3.2 Primary radar. - The Mode S sensor shall be capable of accepting digital surveillance data from a collocated (primary) radar for surveillance processing and correlation along with the beacon data. Collocated means that both primary and beacon antennas use the same pedestal. This data will come from a radar digitizer. The radar target reports, which are made available to the sensor within $3/64$ of a scan, measured from the time of reported azimuth, shall be correlated with beacon reports and coasted tracks.

The basic Mode S sensor shall not track primary radar targets. However, if the contract schedule requires that Appendix IV be implemented, the sensor shall perform surveillance processing of primary radar target reports when interfaced to either an MTD or a SRAP/RDAS.

3.3.3.3 NAS facilities. - The principal user interfaces to the Mode S surveillance and data link networks are to computers located in the NAS ATC facilities. The Mode S sensor shall use two types of digital interface to each facility: a two-way communication and an one-way surveillance link from sensor to ATC. The formats and structure required for these links are described in FAA-RD-80-14. The data rates are specified in 3.5.3.

The sensor shall have up to six surveillance links and six communication links. This capability will serve up to 6 external facilities or systems. ATC data link services will utilize links between the Mode S sensor and ATC facilities. In the initial implementation of Mode S, the only non-ATC data link service will utilize links between the Mode S sensor and the Weather and Communications Processor (WCP). The number of interfaces to be delivered with each sensor shall be as specified in the contract schedule. The surveillance and communications links shall be compatible with service to the NAS Terminal Automation System, the NAS En Route Automation System, and non-ATC (communications only).

3.3.3.4 Not used.

3.3.3.5 Sensor-to-programming support facility. - The sensor shall have a two way, dial-up, 4800 bit/second digital communications link for data transmission between the sensor and the programming support facility (PSF) or sensor support facility (SSF). This communications link will be used for maintenance purposes as described in paragraph 3.8.4.

3.3.4 Sensor functions. - Figure 3.3.4-1 is an overall block diagram of the sensor, illustrating the principal functions and showing the interfaces to other systems. This diagram is not binding upon the actual physical arrangement of hardware and software except as specified in 3.7. The sensor functions, as described in this section, include the general requirements for each major function. The functional logic, the algorithms, and the equations to be used to implement these general requirements are contained in 3.4.

3.3.4.1 Channel management. - Channel management shall regulate the use of the RF channel by the Mode S sensor; it shall determine the nature and timing of each event to accomplish the required Mode S sensor surveillance and communication tasks. To provide surveillance of both ATCRBS and Mode S equipped aircraft with minimal # interference, the RF channel shall be time shared between the ATCRBS-only All-Call mode, ATCRBS/Mode S All-Call mode, ATCRBS mode, Mode S-only All-Call mode, and the " Mode S roll-call mode. In order to provide a maximum of channel time for Mode S activity, the nominal ATCRBS interrogation rate per mode (i.e., A and C) per antenna beamwidth shall be two. The intervals of time devoted to roll-call activity are defined as Mode S periods. Mode S roll-call interrogations shall be addressed to Mode S equipped aircraft under active surveillance (i.e., within the antenna beam). Channel time allocations for each Mode S interrogation and reply shall be based upon a prediction of aircraft range. Channel time shall be scheduled into time periods during which aircraft interrogations are made, or during which aircraft replies are received, so that surveillance and communication tasks of the sensor are carried out for each aircraft while it is under active surveillance. Mode S surveillance and data-link procedures may require more than one interrogation to each aircraft. Therefore, the channel management function shall be able to reinterrogate Mode S equipped aircraft while in the antenna beam. Channel management shall maintain an active target list, comprised of those Mode S targets that are under active surveillance. During a Mode S period one or more roll-call schedules shall be produced as required. A schedule is a set of interrogations and reply times (i.e., transactions), which allow channel management to complete one transaction per target to some or all of the targets on the active target list. The interrogations shall be timed so that nonoverlapping blocks of channel time are assigned to each individual interrogation and reply. If insufficient time is available to schedule all targets on the list, the time is allocated to targets according to preassigned transaction priority. The major channel management functions are channel control, transaction preparation, target list update, roll-call scheduling, and transaction update.

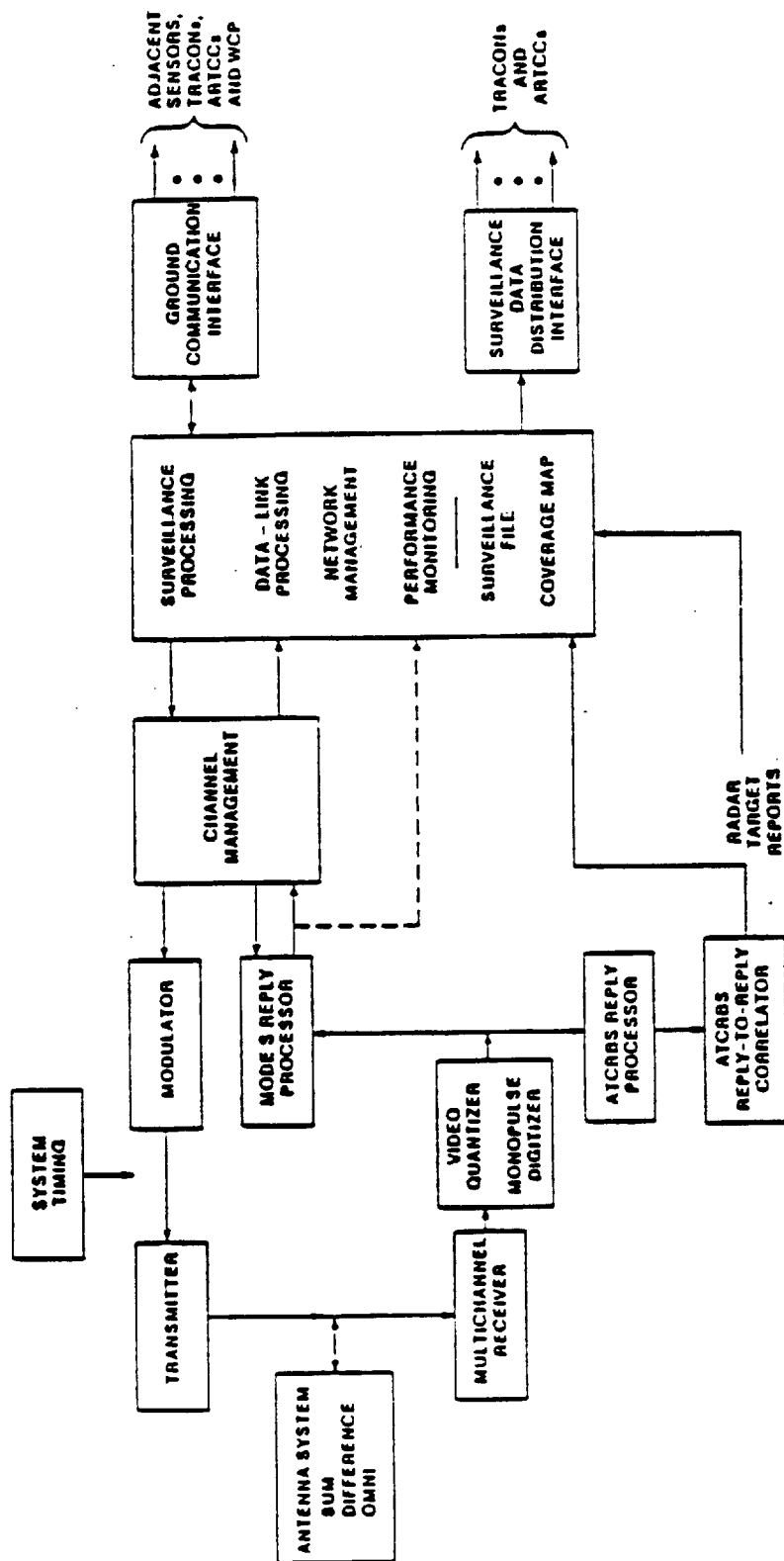


Figure 3.3.4-1. MODE S SENSOR BLOCK DIAGRAM

3.3.4.1.1 Channel control.- All activities that relate directly to the use of the RF channel shall be scheduled and directed by the channel control function. A time-out function shall be provided to insure that the channel does not enter a nonterminating wait due to a failure. Channel control shall be responsible for the timely execution of all RF channel activities including Mode S Roll-Call, ATCRBS/Mode S All-Call, ATCRBS Only All-Call, ATCRBS, and Mode S Only All-Call interrogations. Channel control shall perform ATCRBS/-Mode S period scheduling such that a periodic structure of Mode S and ATCRBS/All-Call periods is imposed on the real-time line. The repetition period of this structure is called the frame time, and the patterned time interval, whose duration is the frame time, is called a frame. A frame contains one or more ATCRBS/All-Call periods and one or more Mode S periods. Each sensor shall always be cognizant of the particular frame structure in use at any given time. Channel control shall generate any desired mode interlace pattern, with ATCRBS/Mode S All-Call, ATCRBS-only All-Call or ATCRBS interrogations. #

3.3.4.1.2 Transaction preparation.- Under channel control, the transaction preparation function shall provide a list of targets that are about to come under active surveillance. All uplink message data and downlink message requests shall be taken into account in determining the number and type of transactions to be prepared by this function. Transaction message data shall be prepared in a manner that satisfies (where appropriate) the message requirements (e.g., protocol, multisite protocol, etc.) contained in the Mode S National Standard. The transaction preparation function under channel control, shall provide a time-ordered list of transactions (i.e., interrogation reply pairings for an aircraft) for those aircraft that are about to come under active surveillance. This data shall be structured to facilitate data retrieval.

3.3.4.1.3 Target list update.- Target list update shall operate under the control of the channel control function. The target list update function shall merge the list of transactions (for new aircraft coming into the antenna beam) as described in 3.3.4.1.2 with the list of transactions for aircraft currently in the beam, and remove aircraft that are no longer under active surveillance or those that have been completely serviced.

3.3.4.1.4 Roll-call scheduling.- This function shall operate under the direction of channel control. The roll-call scheduling function shall operate on the list of aircraft on the active target list (3.3.4.1.3) to produce a schedule. The schedule shall be composed of interrogation and reply periods which fit into the available channel time. If there is insufficient time to schedule at least one transaction each for all aircraft on the active target list, available time shall be allocated based on five levels of transaction priority as follows:

Level 1 - Surveillance and high priority standard messages

Level 2 - High priority uplink extended length messages (ELM's)

Level 3 - Additional standard (lower priority) messages

Level 4 - Uplink ELMs

Level 5 - Downlink ELMs

Those aircraft with an unsuccessful transaction and which are still under active surveillance, shall be rescheduled, where possible, to complete the unsuccessful transaction prior to any other transaction (for that aircraft) and prior to the aircraft's transition to the inactive surveillance state; these interrogations shall be at a higher transmitter power level (selectable by parameter).

3.3.4.1.5 Transaction update.- Under the direction of the channel control function (3.3.4.1.1) the transaction update function shall examine each aircraft reply, and if the transaction is successful, modify that aircraft's transaction schedule such that the next pending transaction shall be carried out in the next schedule. If the transaction was not successful, it shall be repeated in the next schedule and the subsequent pending transaction (for that aircraft) shall be delayed to a later schedule. Transaction update shall direct the transfer of all Mode S replies, as they become available from the Mode S reply processor, to data link processing and surveillance processing. Those aircraft on the active target list that have no transactions pending shall be so labeled.

3.3.4.2 Transmitter/modulator unit.- The transmitter/modulator unit shall accept all digital control inputs from channel management and generate the required RF interrogation signals. For each interrogation to be transmitted, the control inputs shall specify the transmission type (3.3.4.2.1), the power mode, the transmission time, and for a Mode S interrogation, the contents of the Mode S data block. The RF signal contents (coding, parity encoding, etc.) and waveform fidelity shall be in accordance with the Mode S and ATCRBS National Standards. High energy switching for modulation functions shall not be employed. The modulation circuitry shall be protected against active transmitter device arcing, shorting or other modes of failure.

3.3.4.2.1 Transmission types.- The transmitter/modulation unit shall be capable of transmitting the following interrogation types upon command from channel control:

- # (1) ATCRBS Mode A/Mode S All-Call
- (2) ATCRBS Mode C/Mode S All-Call
- (3) Military Mode 2
- (4) Mode S Only All Call
- # (5) ATCRBS Mode A Only All-Call
- (6) ATCRBS Mode C Only All-Call
- (7) Mode S Short Roll-Call
- (8) Mode S Long Roll-Call
- (9) ATCRBS Mode A
- (10) ATCRBS Mode B
- (11) ATCRBS Mode C
- . (12) ATCRBS Mode D

3.3.4.2.2 Transmitter.- Each channel shall include two transmitters, primary and auxiliary. The primary transmitter shall be used for all main-beam transmissions. SLS control transmissions shall be generated by the auxiliary transmitter.

3.3.4.2.2.1 Primary transmitter.- The primary transmitter shall operate in three modes: a high-power Mode S mode, a low-power Mode S mode, and an ATRBS mode. Both Mode S modes shall be capable of handling all of the Mode S interrogation types defined in the Mode S National Standard including extended length message (ELM) transmissions. ATRBS/Mode S All-Call interrogations, ATRBS-only All Call interrogations, Mode S Only All-Call interrogations, and military Mode 2 and ATRBS interrogations are transmitted at the ATRBS power level. All other interrogations are transmitted at either the Mode S-high or Mode S-low power level, the selection being determined by channel control. A common transmitter design shall be used for Mode S Type I, II, and III sensors (1.2.1).

3.3.4.2.2.2 Auxiliary transmitter.- The auxiliary transmitter shall generate the P_3 pulse for Mode S SLS as well as the P_2 or P_1 and P_2 pulses for ATRBS SLS or improved ISLS. It shall be automatically controlled to follow the primary transmitter independent of interrogation type in the sense that for a particular interrogation, the peak auxiliary power equals the peak primary power plus a constant which is manually controllable over a range in steps. The auxiliary transmitter shall follow this nominal performance within a specified tolerance. The duty factor of the auxiliary transmitter shall be consistent with the specified interrogation rates for the primary transmitter.

3.3.4.3 Multichannel receiver.- The multichannel receiver shall process the RF signals which are input from the Mode S Sensor antenna subsystem to provide video and two-level quantized video signals to both the Mode S and ATRBS reply processors. The sensor antenna subsystem shall consist of three channels, each of which has a different azimuthal coverage pattern and gain. These three channels are: 1) Sum or symmetrical pattern channel (Σ); 2) Difference or antisymmetrical pattern channel (Δ); 3) Omnidirectional pattern channel (Ω). These three signals shall be processed by the multichannel receiver to provide signals that can be used for reply detection, reply resolution, discrimination of side and back lobe replies, and off-boresight angle-of-arrival (monopulse) estimation. The multichannel receiver shall preserve the amplitude and phase fidelity as well as the dynamic range of the received signals in order to achieve the specified range and monopulse accuracies.

3.3.4.3.1 Reply pulse processing.- The multichannel receiver shall provide the following video output signals for use by the ATCRBS and Mode S reply processors: 1) a quantized sum (Σ) antenna pattern signal whose detection threshold depends on one of three separately adjustable parameters: a fixed threshold parameter, a signal amplitude dependent parameter, and a time-varying parameter; 2) a quantized signal to indicate when the slope of the sum (Σ) antenna pattern signal exceeds a preset rate, one for the positive direction and one for the negative direction; 3) a quantized signal to indicate pulse reception in either sidelobe or backlobe of the antenna pattern; 4) a monopulse, bipolar video signal proportional to the off-boresite azimuth angle; 5) a signal proportional to the sum (Σ) antenna pattern (Mode S processor only).

The signal dependent threshold parameter in 1) above, is provided to reduce the likelihood of detecting low-level multipath replies. Multipath rejection shall be accomplished by referring the detection threshold (in 1) above) to the amplitude of the detected pulse. The time varying threshold in 1) above shall be provided to minimize occurrence of false replies arising from nearby reflectors. This threshold shall be site adaptable. The output signals and their corresponding threshold detection parameters in 1) and 3) above shall be tailored to provide one set of signals (and parameters) for ATCRBS replies and one set of signals (and parameters) for Mode S replies.

3.3.4.4 Mode S reply processing.- The Mode S reply processing system shall operate on the multichannel receiver outputs, (quantized sum (Σ) signal, quantized sum (Σ) positive and negative slope signals, quantized SLS signal, monopulse video, and the sum (Σ) signal) to detect Mode S roll-call and All-Call replies; to provide estimates of their range and azimuth; and to decode their message blocks. Mode S replies employ parity encoding which shall be utilized by the reply processor to detect and correct errors. The Mode S reply processor shall generate a digitized representation of the quantized video signals which preserves Mode S sensor accuracy, in a format appropriate for reply detection and processing. The reply signals and formats will be in accordance with the Mode S National Standard. Upon processing All-Call replies and roll-call replies the processor shall prepare target reports containing each target's pertinent information.

3.3.4.4.1 Preamble detection.- Mode S replies shall be detected based on the four-pulse preamble waveform preceding the reply data block. A preamble shall be declared when valid pulses are detected in all four positions of the preamble waveform and, in addition, at least two of the pulses are detected with clear leading edges. A reply shall be accepted only if its preamble is detected within a listening "window" surrounding its expected (predicted) reply time. This "window" minimizes the probability of missing the desired reply due to ATCRBS fruit. If no preamble is detected within the "window", the processor shall output a signal to denote this event (3.4.4.8.2). Target range estimation shall be based on the arrival time of the leading edge of the first pulse of an accepted Mode S preamble relative to the start of the listening "window".

3.3.4.4.2 Message bit processing.- Message bit processing shall process the appropriate digitized multichannel receiver signals corresponding to the data block of an accepted Mode S reply and produce a message bit and a confidence bit (high or low) for each information bit in the reply data block. Message bit decisions shall be based on the relative amplitudes of the signals in the two pulse positions (chips) corresponding to each information bit (see the Mode S National Standard). SLS signals shall be used to resolve ambiguous situations in which a signal is received in both pulse positions.

3.3.4.4.3 Monopulse processor.- The monopulse processor shall operate on the monopulse video signal (ψ) to provide an estimate of the monopulse angle for each accepted Mode S reply. The estimates shall be based on an average of a number of acceptable monopulse samples which correlate with a monopulse reference; the monopulse reference shall be derived using two acceptable monopulse samples. Monopulse samples are acceptable if there is a high confidence for the information bit being sampled and:

- (1) it is a first chip sample with a logical high information bit decision, or;
- (2) it is a second chip sample with a logical low information bit decision.

If the monopulse reference is never established, or if an insufficient number of acceptable monopulse samples are available after the establishment of a monopulse reference, this failure condition shall be reported (3.4.4.8.2).

3.3.4.4.4 Message decoding.- Each Mode S message has been encoded in accordance with the Mode S National Standard prior to its transmission to the Mode S Sensor. The messages corresponding to each accepted Mode S preamble shall be decoded by using the inverse of the coding algorithm in the Mode S National Standard. The decoding process shall be used to validate all received Mode S messages and includes error detection and correction of a burst error pattern.

3.3.4.5 ATCRBS reply processing.- Digitized representations of the multichannel receiver quantized video signals that preserve the sensor accuracy shall be provided to the ATCRBS reply processing subsystem in a format appropriate for reply detection and processing. The ATCRBS reply processing subsystem shall be designed to produce accurate, reliable target reports at low interrogation rates using the multichannel receiver video output signals (i.e. quantized sum (Σ) signal, the quantized sum (Σ) positive and negative slope signals, SLS signal and monopulse video). It shall detect ATCRBS replies, estimate target range and azimuth, decode Mode C altitude and discrete (4096) Mode A and Mode 2 codes, and correlate the replies received on successive sweeps to combine replies from the same target into one target report. Reply correlation shall be based on range, azimuth, and high

confidence code and altitude pulses of each reply. The reply signals and format will be in accordance with the ATCRBS National Standard. The processor shall prepare target reports containing estimates of the range, azimuth, codes and altitude based on the range and azimuth of each correlated reply and their high confidence code and altitude pulses.

3.3.4.5.1 Video digitizer.- The video digitizer shall analyze the multichannel receiver video outputs and: (1) reject short pulses; (2) insert pseudo-leading edges (based on the received apparent pulsewidth) between a leading edge and a trailing edge, or between two successive leading edges. Long pulses shall be assumed to have resulted from the overlapping of multiple replies; pseudo-leading edges shall be inserted as estimates of the positions of overlapping ATCRBS reply pulses. A digitized representation of the multichannel receiver video, as processed above, shall be provided for reply detection and processing.

3.3.4.5.2 ATCRBS reply processor.- An ATCRBS reply consists of between two and 16 pulses. The function of the processor is to identify all ATCRBS replies by searching the received pulse train for a framing pulse pair (F_1 , F_2), eliminate phantom pulse pairs due to garbling replies, decode valid code pulse positions, estimate clear code pulses, derive a monopulse estimate for each declared reply using clear pulses, and generate a confidence bit for each pulse which identifies clear pulses that can be used in the subsequent reply correlation processing. The SPI and X pulses shall also be detected and reported if present.

3.3.4.5.2.1 Multiple reply sensing.- Two replies are garbled whenever the replies overlap each other such that the F_1 pulse of the second reply occurs sufficiently close to one of the first reply's pulse positions that it cannot be distinguished from the first reply's pulse. Such situations may cause phantom replies. A phantom reply may also occur when the two real replies are not garbling but close in range. When either case occurs, a phantom bracket may be declared, consisting of a code pulse of the first reply and a code pulse of the second reply. The ATCRBS processor shall eliminate phantom brackets resulting from two other replies and declare the bracket pairs of both real replies. The processor shall declare the bracket pairs of multiple overlapped replies as defined herein whenever possible.

3.3.4.5.2.2 Reply correlation.- A decoded ATCRBS reply shall be compared in range, azimuth, and pairwise high confidence code or altitude data with previously received replies, so that all Mode 2, A, and C replies received from a single target in one scan are grouped into a single target report. If a reply does not correlate with any existing target report file, a new file is started with the reply. Corrections shall be made to prevent the acceptance of a second reply from a transponder that fails to meet the maximum pulsewidth specification.

3.3.4.6 Surveillance processing.- The surveillance processor shall accept target reports from the Mode S reply processor, the ATCRBS reply processor and the radar interface; it shall process these reports in order to maintain target files on all Mode S and ATCRBS aircraft within the sensor's volume of coverage. Track files shall be maintained by tracking Mode S and ATCRBS target reports, correlating current scan reports to these tracks, and updating each track file based on the current scan correlated report information. Beacon reports, radar substitution reports, and radar reports not correlating with beacon reports or tracks shall be sent to designated ATC users. In addition, if the contract schedule requires that Appendix IV be implemented, radar reports shall also be tracked and correlated to form radar-only surveillance files.

3.3.4.6.1 Mode S surveillance processing.- Operating on the one or more Mode S target reports per aircraft per scan, a single target report for a given Mode S address shall be selected for each track and a prediction of its next scan position shall be made. The report selection shall combine finding the report nearest the beam center to maximize azimuthal accuracy, and finding the report with the shortest range (and identical Mode S address) to exclude reflected (false) targets. A Mode S All-Call report with address that does not match an existing track but does match an uncorrelated report from the previous scan shall be tested to see if it is reflected, and if not, it shall initiate a new track file. The still unmatched reports shall be saved for one scan to repeat the process with the newly arrived Mode S All-Call reports. When two or more Mode S replies are undecodable at a consistent range during a beam dwell, the replies are garbled. Based on this, channel management shall schedule stochastic interrogations for these aircraft in the next scan to try to identify the garbling aircraft by reducing the number of aircraft answering the All-Call in that volume of airspace. Mode S tracks are predicted ahead one scan for the scheduling of roll-call interrogations.

3.3.4.6.2 ATCRBS surveillance processing.- ATCRBS reports, consisting of one report per target per beam dwell, shall be edited and corrected as necessary by comparing (correlating) the current scan report with the target tracks. Editing shall eliminate residual fruit and identify possible reflected targets. Correlated target reports shall be used to update the missing or low confidence code bits of the track and to validate the altitude code. Correlation shall be based on range, azimuth, and altitude association level for those reports associated with a single track (and vice-versa). For those reports and tracks with multiple associations, correlation shall be based in addition on code matches, the number of replies in the report, altitude matches, track maturity, and a distance parameter. Upon track update, and whenever the report's Mode A code does not match the track's Mode A code, it shall be assumed that a new Mode A code has been selected in the aircraft. After three scans of a consistent new code, the track code is updated.

3.3.4.6.3 Radar/beacon correlation.- Whenever there is a colocated primary radar, an attempt shall be made to correlate each radar report with a beacon (i.e., ATCRBS or Mode S) report or track. Upon correlation, the beacon report shall be defined to be radar reinforced; a beacon track with no beacon report shall be updated using the radar report (radar substitution) whenever possible.

3.3.4.6.4 Radar surveillance processing.- Under Appendix IV, Mode S sensors operating with the primary radar digitizers will receive one radar report per aircraft per scan plus false alarms and shall perform tracking of radar reports in the same manner as for ATCRBS reports. Radar surveillance processing shall compare (correlate) current scan radar reports with those received on previous scans. Only radar reports not correlating with beacon reports or tracks shall be processed, thus eliminating the possibility of creating two tracks for one aircraft. Both radar target reports that correlate with existing radar tracks and those that fail to correlate shall be output, with a flag signifying which event occurred. Radar report to radar track correlation shall be based on range and azimuth.

Mode S sensors operating with the Common Digitizer (CD) will receive radar reports but shall not perform the report-to-track correlation, smoothing and prediction of these tracks; radar reports shall only be correlated with Mode S and ATCRBS reports, and with coasted tracks in the absence of beacon reports.

3.3.4.7 Data link processing.- All ground/air communications carried out by the sensor shall be managed by the data link processing function. Uplink messages formatted as specified in Mode S ICD shall be accepted from the message routing function (3.4.8.12), processed into an active message list, and made available to the channel management function (3.4.1) for delivery to aircraft under surveillance. Data link processing shall process Mode S replies to determine the success of uplink message delivery and the presence of air-initiated indicators requesting downlink message delivery. Downlink requests shall cause the addition of a suitable entry in the active message list. The downlink replies shall be converted to appropriately addressed messages specified by the Mode S ICDs, including uplink message delivery notices, and made available to message routing for delivery to the appropriate data link users.

3.3.4.7.1 Input message processor.- The input message processor of the sensor shall accept uplink messages formatted as specified in Mode S ICDs from the message routing function (3.4.8.12) and control information from the surveillance file (3.4.6.2). It shall output a priority-ordered active message list for each Mode S aircraft with data link activity based on order received, and the external assigned priority (Mode S ICDs). The uplink messages processed are:

- Tactical Uplink
- ELM Uplink
- Request for Downlink Data
- ATCRBS ID Request
- Message Cancellation Request

3.3.4.7.2 Output message processor.- The output message processor shall extract message data contained in downlink replies from the target records (3.4.1.5), produce output messages or delivery notices formatted according to

Mode S ICDs, and pass these messages (through buffers) to the sensor's message routing function (3.4.8.12) for delivery to the appropriate data link user. On a once-per-scan-per-target basis, the output message processor shall update the active message list using the downlink data. The following downlink replies specified in the Mode S National Standard shall be accepted as inputs for targets on the released target list (3.4.1.4.4)

- Surveillance, Altitude
- Surveillance, Identity
- Comm-B, Altitude
- Comm-B, Identity
- Comm-D

The following messages types specified in the Mode S ICDs shall be output.

- Tactical Downlink (with optional surveillance data)
- ELM Downlink
- ATCRBS ID Notice
- Uplink Message Delivery Notice
- Data Link Capability,

and shall be augmented with a user ID identifying the recipient to the message routing function.

3.3.4.8 Network management

3.3.4.8.1 Purpose and functions.- As Mode S sensors become deployed, multiple coverage will exist at higher altitudes. Mode S shall include a network management function to control the operation of the Mode S sensor in this environment. The purpose of network management is to ensure adequate surveillance and communications for aircraft, provide communications between sensors and ATC facilities, and between several sensors. This shall be accomplished through coordination of sensors' operation for areas of common coverage. Adjacent sensors will not normally be netted and hence shall coordinate their surveillance activities by controlling transponder lockout, or by using the transponder multisite surveillance features. Data link coordination shall be effected through the use of the sensor coverage map and the transponder multisite communication features and assisting the ground communication system in the rerouting of uplink ELM messages when necessary. Where used, netted sensors shall communicate directly with each other, to handoff targets as they cross surveillance boundaries, to assist one another in maintaining continuity of surveillance and data-link service, and to effect rapid target reacquisition in the event of a temporary link interruption.

The basis for network management shall be a sensor coverage map, prestored at each sensor, which defines its responsibilities for targets in each region of airspace. This map shall define the actions of the sensor itself, designate

- † provided shall be determined for two categories of peculiar parts: 1) those for which a complete reprourement package is provided including all necessary specifications, drawings, data rights, and other technical documentation to facilitate a competitive procurement; and 2) those for which a complete reprourement package is not provided.

The quantities provided for each peculiar part with a complete reprourement package shall represent the pipeline spares required for M depots (M=1) servicing S/M sensor sites (S=78 for basic program, S=137 for basic program + option) and shall be determined by the product of each peculiar part failure rate (expressed as failures per 24-hour day), the number of peculiar part applications per sensor site, and a mean depot repair turn around time of N days (N=40). The nominal values of M, S, and N may be altered in the contract schedule. When the calculation results in a fractional number, the quantity provided shall be the next highest integer; in no case, however, shall be quantity of depot spares for any peculiar part with complete reprocrement package be less than one.

The quantities provided for M depot (M=1) of each peculiar part without a complete reprourement package shall represent a 20-year system lifetime requirement, and shall be determined by the product of each peculiar part failure rate (expressed as failures per 24-hour day), the number of peculiar part applications per sensor site, S/M sensor sites (S=78 for basic program, S=137 for basic program + option), 365 days per year, a 20-year life, and a condemnation rate determined through maintainability analysis by the contractor, but not to exceed 5 percent of total repair per year for repairable parts. The nominal value of S and M may be altered in the contract schedule. When the calculation results in a fractional number, the quantity provided shall be the next highest integer; in no case, however, shall the quantity of depot spares for any peculiar part without complete reprourement package be less than one.

3.14.3 Sensor support facility spares.- The contractor shall provide quantities of peculiar part LRU's for the Support Facilities (Appendix II) as defined in paragraph 3.2 of FAA-G-1375 except that cable assemblies, wiring, meters, hardware, card bins, gears, and similar items are added to the list of the parts excluded in the definition. These peculiar part LRU's shall include any specially designed controller or other equipment fabricated especially for the Mode 3 Support Facilities application. Commercially available equipment used for the Support Facilities function, as defined in paragraph 3.1.6 of FAA-G-1375, is excluded from the Support Facilities spares requirement.

The quantity provided for Support Facilities spares shall be calculated in a manner consistent with paragraph 3.14.2 except that S (S=3) Support Facilities sites should be used in the calculation and one depot (M) site. The nominal value of S can be changed in the contract schedule.

†

3.3.4.8.3.2 Sensor coverage and priority. - In general, an ATC control facility will use the data from only one sensor to maintain its track on a particular aircraft. For facilities served by more than one sensor, data on the same aircraft shall be available from more than one sensor to provide an instantaneous backup capability. In regions of airspace visible to more than one Mode S sensor, each Mode S target shall be under roll-call surveillance by at least two sensors simultaneously to provide continuity of surveillance and data-link service in the event of a sensor failure, a ground-to-air link failure, or a sensor-to-sensor communications failure. One such sensor shall be designated as primary and one such sensor shall be designated as secondary. Typically, the data from the sensor designated as primary will be used by the ATC control facility.

3.3.4.8.3.3 Sensor configurations.

3.3.4.8.3.3.1 Non-netted Configuration. - In configurations in which an adjacent assigned sensor is not connected to the local sensor it is necessary to provide a means of surveillance hand-off.

The principal methods for accomplishing this are:

- (a) Site Addressed Lockout. The Mode S transponder can be selectively and independently locked out to special All-Call interrogations originating from up to 15 different sensor sites.
- (b) Cooperative Unlocking. This alternative shall require that each site selectively unlock aircraft in regions of overlapping coverage in order to allow them to be acquired by the adjacent sensor's normal All-Call interrogations.

In the event of failure of sensor-to-sensor communications in an otherwise netted configuration, the sensor affected shall be temporarily treated as non-netted.

3.3.4.8.3.3.2 Netted Configuration. - The use of Mode S lockout to minimize interference on All-Call replies means that provision must be made to hand-off the Mode S discrete address of the aircraft to an adjacent site in areas of multisensor coverage.

- # In a netted configuration, each sensor shall communicate with adjacent sensors via ground lines to ATC facilities to effect such hand-off of targets as they pass from the region of one sensor's coverage to that of an adjacent sensor by transmitting the aircraft's address and position.

In addition, in regions of overlapping coverage, this intersensor communication shall be used to assist in the reacquisition of a lost target.

3.3.4.8.3.4 Coordinate conversion.- When the local sensor requires track data on an aircraft from a remote sensor in the net, the local sensor will receive position and velocity data expressed in the coordinates of the remote sensor, whose ID shall also be transmitted to the local sensor. The position data shall include measured slant range, azimuth and altitude; the velocity data shall include range rate and azimuth rate as determined by the surveillance processing function in the remote sensor. The local sensor shall be required to convert this data into its own coordinates.

3.3.4.8.4 Communications.- The communications functions of network management shall serve to implement the requirements of sensor coverage control (3.3.4.8.2) and surveillance control (3.3.4.8.3), as well as provide for special surveillance requirements, ground-air and air-ground data link requirements, and routing messages to various parts of the Mode S sensor.

3.3.4.8.4.1 Network control messages.- The network control messages shall implement network management between connected sensors by: (1) establishing or terminating track data flow between sensors, (2) establishing sensor priority status, and (3) managing exceptional track alert situations.

3.3.4.8.4.2 Surveillance processing messages.- The network management function shall provide for requests for external track data.

3.3.4.8.4.3 Data-link messages.- A data source may use any sensor which has an aircraft in its track file for the transmission of standard ground-to-air data-link messages to that aircraft. The data-link protocol for the standard ground-to-air message shall operate correctly in areas of overlapping sensor coverage without any requirements for site-to-site coordination, permitting the autonomous delivery of time-critical tactical messages under any circumstances. For aircraft in the track file, for which the sensor is not primary, the sensor will assist the external data link service (e.g. the non-ATC user) in the rerouting of uplink ELM messages to the appropriate sensor. Based on the sensor coverage map function, the sensor will respond to an uplink ELM delivery request with an indication of the sensor(s) that is (are) likely to be primary for the specified aircraft.

3.3.4.8.4.4 Message routing.- This function shall route messages to and from appropriate subsystems, including network management, data-link processing, surveillance processing and performance monitoring. It shall also control dissemination of output messages to data link users whenever those messages are not specifically addressed to a single user.

3.3.4.9 (Not used.)

This space unused intentionally.

3.3.4.10 Performance monitoring.- When deployed, the Mode S sensor is intended to be unmanned and sufficiently reliable and stable so that maintenance personnel need not be stationed in the immediate vicinity. For this reason, the Mode S sensor shall continuously monitor its own performance during normal operations. The sensor shall indicate to connected ATC facilities and to other sensors (when netted) any degradation in its own performance, thereby permitting the network management functions of these sensors to operate in order to share the surveillance and communications task which can no longer be performed by this sensor. Appropriate failure indications shall be provided to maintenance personnel via the RMMS. The performance monitoring function shall be accomplished in part by inserting special test interrogations between the regular Mode S and ATCRBS interrogations, and by processing the returned signals to compare them with certain stored constants in order to verify proper performance. This function relies heavily upon the Calibration and Performance Monitoring Equipment (CPME), specified in Appendix VIII. The CPME is a transponder-like calibration device several of which may be placed at fixed known locations about the sensor. The sensor shall routinely interrogate these devices to obtain a measure of loop performance. The performance monitoring function shall also monitor certain measurement points within the sensor in order to verify satisfactory performance of the sensor.

3.3.4.11 Sensor calibration.- The Mode S sensor makes use of a monopulse technique for the measurement of target azimuth. Monopulse estimates, formed from the sum and difference outputs for individual reply pulses, are used to enter an off-boresight lookup table. The output of this table is off-boresight azimuth. The off-boresight lookup table for each interrogator and processor/antenna combination shall be calibrated, using replies elicited from a CPME. The table shall be recalibrated when required as determined by the Mode S performance monitoring function. As specified herein recalibration requires a brief interruption of normal sensor processing.

3.3.4.12 Sensor start-up.- The Mode S sensor shall follow a detailed procedure, specified herein, upon start-up to effect clock synchronization, program loading, monopulse calibration performance monitoring check, and Mode S acquisition. In addition, it shall be possible to modify any of the site adaptation parameters from a sensor keyboard input device without taking the sensor off line.

3.3.4.13 System timing.- The Mode S sensor shall be equipped with a timing subsystem providing time of year and sensor timing control. The clock shall be driven by a 16 MHz signal. It shall be possible to synchronize the clocks of all Mode S sensors to an external standard. System time shall be continuously available to the transmitter/modulation control unit, the Mode S and ATCRBS reply processors, computer and communications subsystem and the ARIES (Appendix IX). In addition, the sensor timing subsystem shall provide timing references for the generation of both Mode S and ATCRBS interrogation waveforms.

3.3.4.14 Test target generator.- The test target generator shall be configured as built-in test equipment and shall provide the means to periodically verify correct performance of the modulation control unit, the AARTU (3.4.4.7 and 3.4.5.4), the ATCRBS reply processor and the Mode S reply processor digital hardware and receiver. When the TTG is in use, normal system interconnection shall be interrupted. Means for software controlled high speed switching between normal and TTG connections shall be provided.

The test target generator shall provide inputs to the processor unit representing quantized Mode S and ATCRBS replies. These inputs shall be digital signals representing the receiver's video pulse quantizer outputs and 8-bit data words representing the monopulse video signal level. The TTG shall also supply data representing interrogation and processor control blocks normally received from the computer subsystem and simulated ACP and ARP signals normally received from the antenna's azimuth pulse generator. The TTG shall utilize the receiver built-in test equipment during the receiver checks.

3.4 Functional requirements of the sensor.- This section, together with the requirements sections of relevant appendices, specifies a Mode S sensor capable of operating with a single face or back-to-back antenna and with auxiliary equipment. Each of the following subsections specifies a major function of the system, necessary in the realization of the overall performance relative to each face, while the Appendices specify the required performance in the back-to-back mode, and in extended configurations. Exact formats and bit assignments for intrasensor interfaces, and layouts and structures will be determined by the contractor's hardware and software implementation choices. In addition to the requirements specified for the individual functions, the sensor shall be designed so that all functions operate together, with each function performed with the frequency and timing, relative to other functions, as specified herein.

(a) Definition of Azimuth unit (Au) and Range unit (Ru).- The sensor shall operate with an antenna azimuth register of 14 bits referenced to true north, and shall employ a basic clock frequency of 16 MHz. Consequently, throughout this specification, the least significant bit (LSB) in azimuth

is called the Azimuth Unit,

$$Au = 2^{-14} * 2\pi \text{ radians.}$$

Within the sensor azimuth shall be measured in Azimuth Units.

The LSB in time is 2^{-4} μ s. Corresponding to this LSB in time, range is expressed as the time required in sixteenths of a microsecond for light to travel to that range. Thus, range is expressed in Range Units:

$$Ru = 2^{-4} \mu s.$$

Within most of the sensor and between sensors, range shall be carried as two-way range in Ru's. In converting data for transmission to NAS Terminal and En Route range shall be expressed as one-way range in nmi.

(b) Parameter notation.- Parameters specified herein utilize the following notation:

$$p = w(x-y,z).$$

Meaning: The parameter p shall be given the nominal value w. All functions using that parameter shall accept a range of parameter values from x to y in steps of z.

(c) Complex signal notation.- In the sections dealing with analog signals (especially Section 3.4.2, 3.4.3, 3.4.4, 3.4.5, and 3.4.10), characters Σ , Δ , Ω , A, B, etc., denote complex signal amplitudes, and the operator j denotes a 90° phase shift as in customary usage.

(d) Binary sequence notation.- The following notation is used for binary sequences:

- (1) The sum modulo-2 of two binary sequences is denoted as

$$A \oplus B = (A_1 \oplus B_1, \dots, A_n \oplus B_n)$$

i.e., the binary sequence whose components are modulo-2 sums of corresponding components of each sequence.

- (2) The product $A \cdot B$ is defined as

$$A \cdot B = (A_1 \cdot B_1, \dots, A_n \cdot B_n)$$

where $A_1 \cdot B_1$ denotes the logical AND operation with components A_1 and B_1 .

- (3) The logical sum $A + B$ of two binary sequences is defined as

$$A + B = (A_1 + B_1, \dots, A_n + B_n)$$

where $A_1 + B_1$ denotes the logical OR operation with components A_1 and B_1 .

- (4) The magnitude of a binary sequence $|A|$, is defined as the number of '1's in the sequence.

(e) Conventions.— Unless otherwise specified, "set" and "reset" when referring to a flag, indicator, or parameter, shall mean "set to one" and "reset to zero", respectively.

(f) Symbology.—

*	denotes "multiply by"
($\hat{}$)	denotes "estimated value"
($\bar{}$)	denotes "average value", or "complement of"
	denotes "absolute value"
$x \rightarrow y$	denotes "replace y by x"

This space intentionally unused.

3.4.1 Channel management.

3.4.1.1 Overview.

3.4.1.1.1 Purpose.- Channel management regulates the use of the RF channel by a Mode S sensor. The nature and timing of each event taking place on the channel is determined by channel management in order to accomplish the surveillance and communications tasks of the sensor. Channel management controls both the roll-call and all-call activities of the sensor.

3.4.1.1.2 Interfaces.- Channel management requires the predicted position and the list of pending data link messages for each roll-call target. This information is taken as input from the surveillance file and from the active message lists, associated with that file, before each roll-call target enters the antenna beam. After a number of targets have left the beam, channel management outputs a released target list, to be used by the surveillance and data link processing functions. The released target list includes the number of replies received for each target and indications of successful message delivery. The information content of the replies and the positional data derived from the replies is made available to the surveillance and data link processors by channel management.

Channel management also interfaces with transmitter/modulation control and with both Mode S and ATRBS reply processors. Channel management outputs consist of both ATRBS and Mode S interrogation control commands to transmitter/modulation control, and reply control commands to the reply processors. Mode S roll-call replies are available as input to channel management from the Mode S reply processor.

The remaining interfaces provide channel management with access to the system clock and the antenna azimuth register (3.4.13.5).

3.4.1.1.3 Definitions.- The definitions of some of the basic terms, specific to channel management, are given here.

- (a) ATRBS interrogation - Any interrogation that elicits ATRBS replies from ATRBS or Mode S transponders.
- (b) ATRBS/All-Call - A term that refers to non-selective interrogations, i.e., the ATRBS interrogation or the ATRBS/Mode S, ATRBS-Only, or Mode S-Only All-Call interrogations.
- (c) ATRBS/All-Call schedule - The pattern of successive ATRBS/All-Call interrogation times and interrogation modes is called an ATRBS/All-Call schedule. The generation of these times and modes is called ATRBS/All-Call scheduling.

- (d) Active target - A Mode S roll-call target or acquisition track target presently within the antenna beam and awaiting interrogations from the sensor is said to be an active target. The set of active targets constitutes the active target list.
- (e) Transaction - A particular pairing of an interrogation type with a reply type, for a Mode S roll-call target, is called a transaction. A standard transaction contains a single interrogation paired with a single reply. An extended length message (ELM) transaction may contain either multiple interrogations or multiple replies. There are two kinds of ELM transactions. An uplink transaction contains up to sixteen interrogations, paired with a single reply. A downlink ELM transaction contains a single interrogation, paired with up to sixteen replies.
- (f) Surveillance transaction - The first transaction which is executed for a target which has just entered the antenna beam is called a surveillance transaction. The range, azimuth and altitude obtained from this reply will usually form the basis for position update on the target in the corresponding scan. The interrogation for a surveillance transaction will be a discretely addressed Mode S interrogation for normal tracks and a Mode S Only All-Call for acquisition tracks.
- (g) Transaction record - The transaction record is a set of information which completely characterizes a transaction. This record includes the uplink message information bits (if present) and, when fully prepared, contains a completely formatted interrogation, except for error encoding, as well as all information required to form interrogation and reply control commands (3.4.1.5.2).
- (h) Target transaction block - Before each Mode S roll-call target enters the antenna beam, a set of transaction records is partially prepared. This set of records, together with a header called the target record, containing target address, range, and other information is called a target transaction block.
- (i) Schedule - A set of transactions, one per target, together with assigned times for the start of each interrogation and each reply listening period, for each transaction in the set, is called a schedule, or roll-call schedule. When an interrogation is transmitted at the time given in the schedule for a given transaction, the reply may be expected from the discretely-addressed aircraft within the corresponding reply listening period.
- (j) Mode S period - An interval of time which is reserved for Mode S roll-call scheduling.

3.4.1.1.4 Major subfunctions.- Channel management subfunctions shall be:

- (a) Channel control.
- (b) Transaction preparation.
- (c) Target list update.
- (d) Roll-call scheduling.
- (e) Transaction update.

Although channel management is described as having a distinct channel control subfunction, it is permissible to distribute this subfunction among the other channel management subfunctions if required by the software system design.

3.4.1.1.5 Major files.- The only major file internal to channel management is the active target file, which consists of a target transaction block for each active target.

3.4.1.1.6 Channel management operation.- A block diagram of the channel management function is shown in fig. 3.4.1-1. Each of the five major subfunctions listed in 3.4.1.1.4 is shown as a block, and the active target list appears as an explicit storage area. Other storage areas are indicated as buffers for the temporary storage of information.

The channel management function is specified as a serial algorithm for implementation in a single computer. Other implementations of channel management that use multiple computers and parallel processing of subfunctions may be used.

Channel control plays the role of executive in this subsystem, controlling the execution of the other subfunctions. Channel management shall be responsible for ATCRBS/All-Call scheduling and for the generation of roll-call schedules occupying Mode S periods on the RF channel. Transaction preparation shall be directed by channel control to obtain information on roll-call targets from the target files and to partially prepare a target transaction block for each of these targets, shortly before the targets enter the antenna beam.

At appropriate times, target list update shall be directed by channel control to update the active target list, adding to it the target transaction blocks of targets about to enter the beam, and removing from it the target transaction blocks of targets no longer within the beam. After the active target list has been updated, channel control shall direct roll-call scheduling to generate a series of one or more schedules.

Before each schedule, channel control shall provide roll-call scheduling with the remaining channel time available before the end of the Mode S period in progress. During the execution of each schedule, transaction update shall monitor the success or failure of each transaction and prepare the active target list for the next schedule. The roll-call scheduling output shall be a time-ordered stream of interrogation and reply control commands.

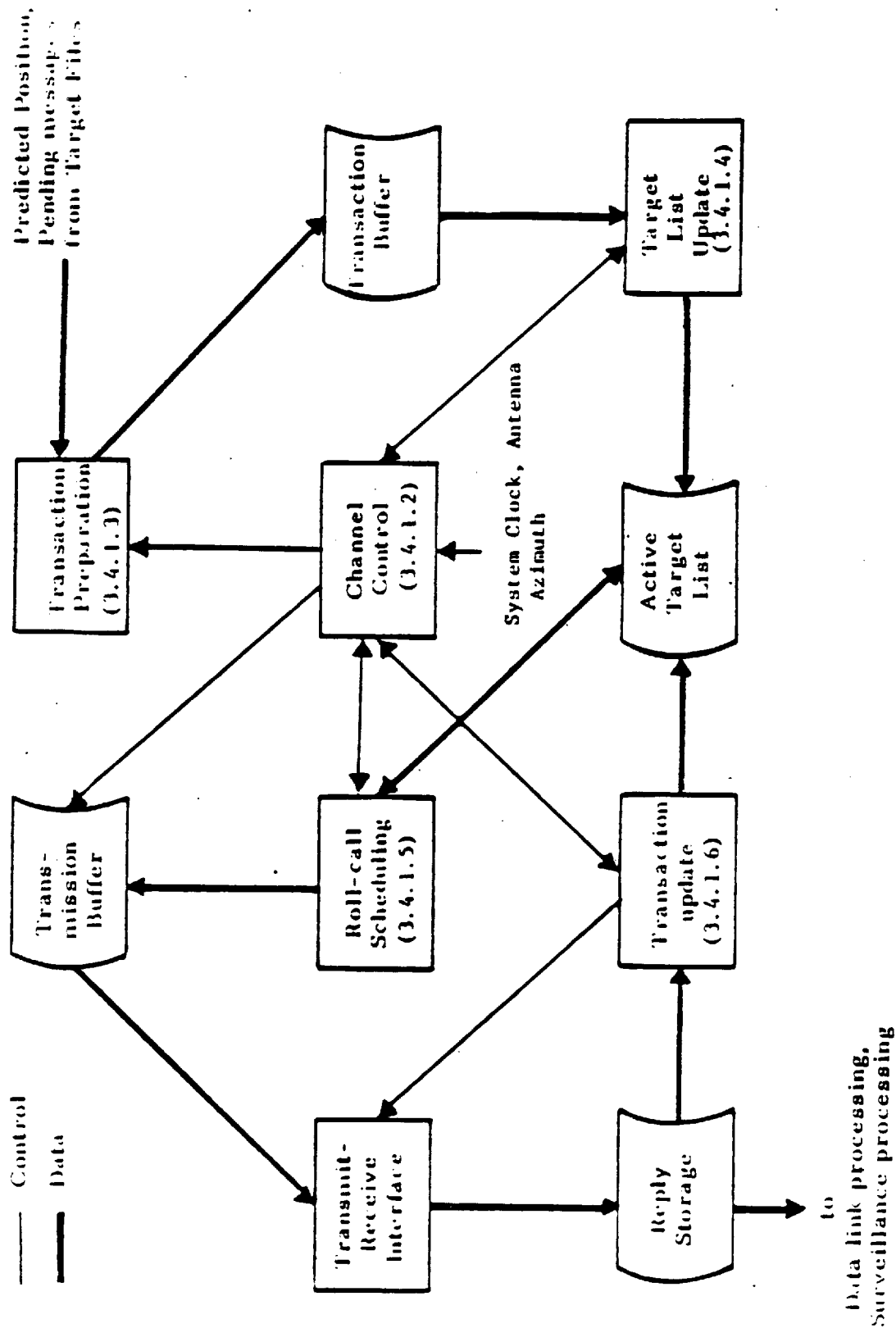


FIGURE 3.4.1-1

CHANNEL MANAGEMENT BLOCK DIAGRAM

3.4.1.1.6.1 Lost channel time. - Roll-call scheduling shall be accomplished in such a way that when handling the maximum loading specified in Table 3.3.2.5-1, or any subset of this loading, processing delays:

- (a) do not cause lost channel time at the beginning of a Mode S period,
- (b) do not cause lost channel time during the first schedule of a Mode S period,
- (c) when averaged over any four consecutive Mode S periods, cause no more than $250 \mu\text{sec}$ lost channel time per schedule for each of the successive (i.e., 2nd, 3rd, etc.) schedules in a Mode S period.

A period of $1200 \mu\text{seconds}$ is permitted from the receipt of a reply from a given aircraft to the time of the next interrogation to that aircraft. Lost channel time for reinterrogation of the same aircraft shall only be charged for delays that exceed the permitted $1200 \mu\text{sec}$.

3.4.1.2 Channel control.

Note: The following requirements are based upon the use of a subset of the station time clock. Other implementations that use the entire station time clock may be utilized if approved by the Government.

3.4.1.2.1 Channel timing. - All activities of the Mode S sensor which relate directly to the use of the RF channel shall be regulated by channel control. Channel control shall be responsible for the timely preparation of ATCRBS/All-Call interrogation control commands, and also for the execution of all other channel management subfunctions. Channel control shall be given access to the current values of the time-of-year (TOY) clock, the station time clock, and antenna (boresight) azimuth, by means of read-time and read-azimuth requests. A read-azimuth request shall provide channel control with the current contents of the antenna azimuth register, which indicates antenna pointing direction in azimuth units (approximately 0.022°). The antenna azimuth register is driven by a 14-bit antenna shaft encoder. Time is provided as the current contents of the TOY and station time clocks. The response to a read-time request shall be a time message representing the 36 bits of the TOY clock plus the 16 most significant bits of the 23-bit station time clock. The 15 most significant bits of the station time clock are referred to as the time unit word. The least significant bit of the time unit word shall represent $16 \mu\text{s}$ which is referred to herein as a time unit. Channel control shall issue interrogation control and reply control commands, which specify transmission times and reply listening period times, in the form of 16-bit words which are to be compared to the 16 lowest order bits of the transmission control register (referred to as the range unit word).

Channel control is activated intermittently. The final action of channel control, during an active period, is often the issuance of a command. Channel control commands shall be of three kinds, as follows:

- (a) ATCRBS/Mode S All-Call, ATCRBS, ATCRBS-only All-Call, or Mode S-Only All-Call interrogation control commands,

- (b) Schedule release commands, and
- (c) Subfunction enabling commands.

The preparation of these commands is specified below. A schedule release command releases Mode S roll-call interrogation commands from the transmission buffer to transmitter/modulation control. After issuing a command, channel control shall enter an inactive state, to be restored to activity by a completion notice. When an interrogation control command is executed by transmitter/modulation control, the completion notice consists of a time word, sent by transmitter/modulation control upon transmission of the P_1 pulse, and indicating the time of that transmission. The execution of an enabling command by another channel management subfunction always results in a completion notice to channel control. Upon receipt of a completion notice of this latter kind, channel control shall issue a read-time request. In some cases, channel control also issues a read-azimuth request in response to a completion notice. Channel control is always cognizant of what activity is in progress on the RF channel when it is reactivated, and it is capable of determining the future sequence of activities on the channel. In every case, a time-out shall be provided to ensure that channel control does not enter a non-terminating wait state due to the failure of another subfunction.

Whenever reactivated, channel control shall determine its next responsibility, according to rules specified below. If the next command will be an interrogation control command, or a schedule release command, channel control shall determine the time interval from the current real time reading to the intended time of interrogation transmission or schedule release. If this time interval exceeds 4.096 ms, channel control must delay issuance of this command until the interval is less than 4.096 ms in order to avoid time ambiguity.

3.4.1.2.2 ATCRBS/Mode S period scheduling. - Channel control is responsible for the location of ATCRBS/All-Call and Mode S periods on the real time line. A time interval starting with a non-selective interrogation (either ATCRBS/Mode S All-Call, ATCRBS, # ATCRBS-only All-Call or Mode S only All-Call) and extending for the duration of the # maximum listening period is defined as an ATCRBS/All-Call period. A time interval devoted to Mode S roll-call interrogations and the corresponding Mode S reply listening periods is defined as a Mode S period. Mode S periods and ATCRBS/All-Call periods never overlap, and they may be separated by inactive periods, during which # neither activity takes place. However, an ATCRBS/All-Call period initiated by an # ATCRBS-only All-Call interrogation may overlap an ATCRBS/All-Call period initiated by a Mode S only All-Call if the interrogation command times are separated by a sufficient amount of time to ensure that the first interrogation has been completed by the modulation control unit before the second interrogation is required. (Note that an additional separation of the interrogations may be required to allow the modulation control unit to set up for the second interrogation). ATCRBS/Mode S period scheduling denotes an activity of channel control in which the sequence of actual beginning and end times of these periods is determined.

A periodic structure of Mode S and ATCRBS All-Call periods is imposed on the real time line. The repetition period of this structure is called the frame

time, and the patterned time interval, whose duration is the frame time, is called a frame. A frame contains one or more ATCRBS/All-Call periods and one or more Mode S periods. In addition, once during every frame, there shall be a Test Target Generator (TTG) test period, lasting 450 μ sec. Provision shall be made for enabling the activity of the TTG (3.4.10.3.5.6 and 3.4.14.8) during the TTG test period except in sectors where such scheduling would conflict with the ability of the ATCRBS Reply-Reply Correlator to handle peak loading and delay requirements specified in 3.4.5.6.7. Each sensor shall always be cognizant of the particular frame structure in use at any given time.

Channel control shall be site adapted with a complete characterization of the frame structure with which the sensor is to operate. ATCRBS/All-Call, Mode S, and TTG period beginning and end times, relative to a frame beginning, shall be input with a precision (least significant bit) of 16 μ s. No frame time will exceed 524 ms. Whenever given a real time reading, channel control shall have the capability to determine all future beginning and end times of ATCRBS/All-Call and Mode S periods in time units. To accomplish this, channel control must know the real time value of the most recent frame beginning time. The input characterizing the frame structure shall identify the delay mode of each ATCRBS/All-Call period. The ATCRBS/All-Call delay mode is defined as the method by which ATCRBS (or Mode S Only All-Call) interrogation time is to be determined. The possible methods are specified in 3.4.1.2.3.2 and 3.4.1.2.3.3.

3.4.1.2.3 ATCRBS/All-Call scheduling. - The generation of the sequences of ATCRBS/All-Call interrogation modes and interrogation times is referred to as ATCRBS/All-Call scheduling. Channel control shall be responsible for ATCRBS/All-Call scheduling. This shall include the scheduling of Mode S-Only All-Call interrogations in the case where site addressed lockout is employed.

3.4.1.2.3.1 ATCRBS mode interlace. - Channel control shall generate any desired mode interlace pattern, with ATCRBS/Mode S All-Call, ATCRBS-only All-Call or ATCRBS interrogations, under control of an input table, entered in the sensor memory as a part of program adaptation.

3.4.1.2.3.2 ATCRBS/All-Call interrogation time. - ATCRBS/All-Call interrogation time is related to the beginning of the ATCRBS/All-Call period in either one of the following ways:

- (a) Interrogation at the beginning of the ATCRBS/All-Call period,
- (b) Each interrogation following the beginning of an ATCRBS/All-Call period by a delay chosen sequentially from a delay sequence.

The sequence of delays referenced above may be a pseudo-random sequence, computed sequentially, or a stored sequence of up to 8 values. Channel control shall have the capability to determine interrogation times in each of the two ways defined in (a) and (b). Specifically, given a real time reading, channel control shall have the capability to compute the time of interrogation of the next forthcoming interrogation, according to the input mode of operation. If a delay sequence is to be used, channel control shall be able to introduce a delay selected sequentially from a stored set of values, or to compute delays sequentially. If computed delays are used, channel control shall compute a pseudo-random sequence, using a standard algorithm for random number

generation. If random number generation is used, the distribution of the generated numbers shall be uniform over an interval from RANMIN to RANMAX. RANMIN and RANMAX are system parameters, (0-512, 16), in range units.

The interrogation time determined according to the above rules is the intended time of transmission of the P_1 pulse of an ATCRBS/All-Call interrogation. It should be noted that the stored or computed delay sequence, referenced in (b) above, can be related to the stored ATCRBS mode interlace pattern, so that the P_3 pulses of successive ATCRBS interrogations can be made to occur in a predetermined timing sequence.

3.4.1.2.3.3 Interrogation control commands.- Whenever channel control is notified of an ATCRBS transmission or Mode S Only All-Call transmission or determines (according to rules specified below) that a Mode S period has ended, channel control shall determine whether or not the next period of channel activity is an ATCRBS/All-Call period. This determination is made on the basis of the frame structure in use, as specified in 3.4.1.2.2. If the next command must be an ATCRBS interrogation or Mode S-Only All-Call interrogation control command, channel control shall:

- (a) Determine the proper ATCRBS/All-Call interrogation mode, for the mode of operation in use, as specified above;
- (b) Determine the proper P_1 transmission time, for the mode of operation in use, according to the rules specified above;
- (c) Determine the listening interval, as specified below;
- (d) Prepare an interrogation control command, as specified in Fig. 3.4.2.1(b); also prepare a pair of receiver control blocks as specified in 3.4.2.1; and,
- (e) Send the command to transmitter/modulation control, delaying delivery as specified in 3.4.1.2.1, if necessary.

3.4.1.2.3.4 Listening period.- The listening period for interrogation control commands is azimuth dependent. This listening period shall never exceed the duration of the ATCRBS/All-Call period corresponding to the frame structure in use at any given time. An ATCRBS/All-Call listening period look-up table is provided and maintained by network management. The table is called the ATCRBS/radar range mask, and its structure and maintenance are specified in 3.4.8.3.6. The table contains listening periods, expressed in eight-bit field (LSB = $16\mu s$), and it is entered by azimuth, quantized in units of 256 azimuth units. Whenever an interrogation control command is to be prepared, channel control shall use the bore-sight azimuth predicted for this interrogation and look up the listening period in the table described above. The predicted azimuth may be converted to a table entry index by means of a right shift of eight bits. The prediction of azimuth is carried out as follows: Whenever

channel control receives notification of the transmission of an interrogation, channel control shall read the antenna azimuth register and store both the azimuth and transmission time obtained. When the next transmission time is determined, channel control shall determine the time interval, T, between the last and next transmission. This interval, T, is computed in time units, with least significant bit equal to 16 μ s. The predicted azimuth is determined from the formula

$$\theta_{\text{next}} = \theta_{\text{last}} + T/\text{SCAN}.$$

The symbols in this formula have the following significance:

θ_{next}	Predicted azimuth.
θ_{last}	Azimuth of last ATRBS/All-Call transmission.
T	Time interval from last to next ATRBS/All-Call transmission.
SCAN	Antenna scan rate parameter.

The system parameter, SCAN, represents the inverse scan rate, in time units per azimuth unit. For scan rates greater than 10 rpm, the parameter shall be set to 16, and for scan rates less than or equal to 10 rpm, the parameter shall be set to 32.

Note: These values correspond to nominal scan rates of 14.3 rpm and 7.2 rpm respectively. Over the range of possible antennas to be used, the errors introduced by these approximations are acceptable.

The predicted azimuth shall be stored until it is required in the preparation of the next forthcoming interrogation control command.

3.4.1.2.4 Mode S period prediction.- During the course of a Mode S period, channel control shall retain values of the following quantities:

- (a) Present Mode S period end time,
- (b) Next forthcoming Mode S period beginning time,
- (c) Next forthcoming Mode S period end time, and
- (d) Next forthcoming Mode S period cutoff azimuth

The present Mode S period end time is the former value of the "next forthcoming" Mode S period end time; the other quantities are computed according to rules specified herein. Commands from and responses to channel control during the course of a Mode S period are specified below, together with the circumstances which cause channel control to determine that no further scheduling activity is to take place in the present Mode S period. This latter

condition will be denoted by the phrase: Mode S scheduling completed. When channel control determines that Mode S scheduling is completed, channel control shall:

- (a) Issue a read-time request,
- (b) Issue a read-azimuth request, and,
- (c) Determine if the next forthcoming period of activity on the RF channel is to be an ATCRBS/All-Call period or a Mode S period.

The result of (c) above shall always be that an ATCRBS period follows a Mode S period. Channel control shall then prepare an interrogation control command, as specified in 3.4.1.2.3.3. In this case, the two steps specified as (b) and (c), above, shall be carried out again when notification of interrogation is received, as already specified in 3.4.1.2.3.3.

Eventually, it will happen that the next RF activity is to be a Mode S period. This fact shall be recognized by channel control as a result of the rules specified above. Concurrently with this recognition, channel control will have determined the current values of real time and antenna azimuth. Let the values so determined be denoted by T and θ , respectively. Let the beginning and end times of the forthcoming Mode S period be T_1 and T_2 , and let the corresponding cutoff azimuth be θ_{cut} . After determining that the next RF activity is a Mode S period, channel control shall:

- (a) Set a variable called schedule start time equal to the present value of T_1 ,
- (b) Set a variable called Mode S period end time equal to the present value of T_2 ,
- (c) Send an enabling command to target list update, including the present value of θ_{cut} ,
- (d) Compute new values of T_1 and T_2 , by predicting the time of the next following Mode S period in the frame, as specified in 3.4.1.2.2,
- (e) Compute a new value of θ_{cut} for use during the ATCRBS/All-Call interval following the present Mode S period, and a value of θ_{new} , according to rules specified below, and
- (f) Send an enabling command to transaction preparation, including the value of θ_{new} computed in (e) above.

The azimuth angles, θ_{new} and θ_{cut} , shall be computed from the following formulas:

$$\theta_{\text{new}} = \theta + \theta_{\text{prep}} + (T_1 - T)/\text{SCAN}$$

$$\theta_{\text{cut}} = \theta - \theta_{\text{half}} + (T_2 - T)/\text{SCAN}$$

The symbols in these formulas have the following significance:

θ_{new}	New azimuth limit for transaction preparation.
θ_{cut}	New cutoff azimuth for future use by target list update.
θ_{half}	Antenna half beamwidth, a system parameter ranging from zero to 128 azimuth units, in steps of 4 azimuth units. The appropriate value depends upon the antenna in use.
θ_{prep}	$\theta_{\text{half}}/K_{\text{half}}$ $K_{\text{half}} = 2(1-4, 0.1)$
T	Real time read by channel control just before executing this computation.
T_1	Beginning time of future Mode S period, just computed as specified in (d) above.
T_2	End time of future Mode S period, just computed as specified in (d) above.
SCAN	System parameter, specified in 3.4.1.2.3.4.

Channel control shall be provided with the value of θ_{half} and K_{half} as adaptation parameters.

3.4.1.2.5 Mode S period control.- After completing the activities specified in 3.4.1.2.4, channel control shall become inactive, awaiting a completion notice from target list update. No completion notice will be sent from transaction preparation. Upon receipt of a completion notice from target list update channel control shall issue a read-time request. Channel control shall then commence Mode S period control activity, as specified herein. This activity consists of the authorization of a sequence of Mode S roll-call schedules, to be executed during the coming Mode S period. For each roll-call schedule, the following sequence of actions shall take place, according to rules specified below:

- (a) Channel control shall compute a schedule start time and an available time. The available time shall be set to zero if the active target list is empty.
- (b) Channel control shall determine whether a schedule will be authorized, or whether Mode S scheduling is completed for the present Mode S period.
- (c) If Mode S scheduling is complete, channel control shall determine what action to take next, as specified in 3.4.1.2.2, 3.4.1.2.3 and 3.4.1.2.4.

- (d) If Mode S scheduling is not complete, channel control shall send an enabling command to roll-call scheduling. This command shall contain the schedule start time and the available time.
- (e) Channel control shall then send a schedule release command, delayed if necessary, to the transmission buffer, and enter the inactive state.
- (f) Channel control shall be reactivated by a notice of completion by roll-call scheduling. If this notice indicates that no schedule is to be produced by roll-call scheduling, channel control shall proceed as in (c) above.
- (g) If roll-call scheduling generates a schedule, it will send an appropriate completion notice containing the actual schedule end time to channel control. Channel control shall enter the received schedule end time into the location of the variable schedule start time for future use. Channel control shall activate transaction update and then become inactive.
- (h) Channel control shall be reactivated by a notice of completion from transaction update. Upon receipt of this notice, channel control shall issue a read-time request and repeat the above sequence of steps, beginning with (a) above.

Each time channel control executes step (a), above, it will have available a real time value and a schedule start time. If step (a) is executed in response to a completion notice from target list update, the real time will represent the time of arrival of that notice and the schedule start time will equal the beginning time of the Mode S period whose activity is presently being regulated. If step (a) above is executed in response to a completion notice from transaction update, the real time will represent the time of arrival of that notice and the schedule start time will equal the end time of the previously authorized roll-call schedule. In either case, let the real time value be denoted by T. Channel control shall compute the sum of T and the system parameter Δ_{sched} , nominally equal to 6 (0-16, 1) time units. This parameter represents the allowed computational delay, inherent in roll-call scheduling, before the first roll-call interrogation command is available following the enabling of that subfunction. Channel control shall compare the sum, $T + \Delta_{\text{sched}}$, to the current value of schedule start time. If the sum exceeds the schedule start time, the value of the sum shall be entered in schedule start time.

Channel control shall compute available time according to the formula

$$AT = PE - SS.$$

The symbols in this equation shall have the following significance:

AT	Available time, in time units.
PE	End time of Mode S periods whose activity is presently being regulated, in time units.
SS	Schedule start time, computed as specified above, in time units.

If available time exceeds the value of the system parameter, S_{min} , channel control shall send an enabling command to roll-call scheduling. The parameter S_{min} , nominally 16(0 -60, 4) time units represents the minimum time for which it is feasible to attempt the generation of a roll-call schedule. If available time does not exceed S_{min} , channel control shall determine that Mode S scheduling is complete, and proceed as in step (c) above.

Channel control shall include an available time and a schedule start time in the enabling command sent to roll-call scheduling. These times shall be in range units. Channel control shall convert available time and schedule start time from time units to range units, by executing a left shift of one byte, observing overflow. If overflow occurs in available time, i.e., if available time exceeds 4.096 ms (the range unit word, Fig. 3.4.13-2), roll-call scheduling shall be informed of the amount of the overflow.

After enabling roll-call scheduling, channel control shall send a schedule release command to the transmission buffer. This command shall authorize the transfer of roll-call interrogation control commands from the transmission buffer to transmitter modulation control. If schedule start time overflow occurred, channel control shall delay the delivery of the schedule release command as specified in 3.4.1.2.1. Immediately after receiving a completion notice from roll-call scheduling, channel control shall send an enabling command to transaction update.

When channel control determines that Mode S scheduling is complete, a schedule inhibit command shall be sent to the transmission buffer. This command shall prevent the transfer of roll-call interrogation control commands from the transmission buffer to transmitter/modulation control.

In making computations with quantities expressed in time units, channel control shall recognize the occurrence of overflow. This overflow will occur if the prediction of a future event (such as an ATRBS interrogation) leads to a number which equals or exceeds 524.288 ms, since a time unit is 16 μ s and a time unit word contains 15 bits, exclusive of sign. Channel control shall take due account of overflow when computing available time and establishing the times of future events.

3.4.1.3 Transaction preparation.

3.4.1.3.1 Inputs.- Transaction preparation shall accept enabling commands from channel control. Each enabling command shall contain a new azimuth limit for the use of transaction preparation in fetching new targets. Data on new targets shall be obtained by transaction preparation from the target files, namely, the surveillance file and the active message lists. All information in these files shall be available to transaction preparation when this function is enabled. The surveillance file shall be structured in such a way as to permit a between-limits search based on earliest likely azimuth. Earliest likely azimuth is computed for each roll-call target by the surveillance processing function, as specified in 3.4.6.10.4.3. The between-limits search shall make available to transaction preparation the contents of both the surveillance file and the active message file for all targets which are found as a result of the search. An acceptable way of structuring the surveillance file shall be a sorting of targets in the file into azimuth bins. The size of such a bin shall not exceed 16 azimuth units. If this method is used, the surveillance file shall be resorted on earliest likely azimuth upon completion of track updating.

3.4.1.3.2 Outputs.- The major output of transaction preparation is a set of target transactions blocks, one for each of the targets fetched by transaction preparation in response to a channel control enabling command. When this task is complete, transaction preparation shall assign an old azimuth limit, by equating it to the current new azimuth limit. The target transaction blocks produced by transaction preparation shall be made available to target list update whenever the latter function is enabled. The interface between these functions is shown in fig. 3.4.1-1 as the transaction buffer.

3.4.1.3.3 Fetching new targets.- When enabled by channel control, transaction preparation shall execute a between-limits search of the surveillance file, based on earliest likely azimuth. A target shall be accepted by the search if its earliest likely azimuth exceeds the old azimuth limit and does not exceed the new azimuth limit. An equivalent rule shall be adopted if bin-sorting of the surveillance file is used. The surveillance file record of each target accepted by transaction preparation in this search shall be marked as closed by setting an appropriate bit. This record shall remain closed (unavailable to other sensor data processing functions) until the closure bit is reset by data link processing.

If a technique is employed which allows for transaction preparation to execute more than 1 Mode S period ahead of the beam, look ahead processing shall be limited to 1 sector (11.25 degrees) ahead of the beam.

3.4.1.3.4 The target record.- A header for each target transaction block shall be prepared by transaction preparation. This header is called a target record.

3.4.1.3.4.1 Composition of the target record.- Each target record shall contain the following information, obtained from the surveillance file:

- Mode S address
- Acquisition track flag
- Range delay (earliest likely range, 3.4.6.10.4.3)
- Range guard
- Last likely azimuth
- Primary indicator (Sensor Priority Status, PS)
- Unconnected sensor flag (USF)
- ATCRBS ID request (AI)
- Capability request flag (CAP)
- Mode S lockout indicator (DL)
- Broadcast message number (3.4.1.6.5.3.7.2)

In addition, each target record shall contain the following information, generated by transaction preparation or subsequently enabled functions:

- Range completion
- Azimuth completion
- Target completion
- Power-programming control
- Remaining tries
- Comm-B state
- Comm-C state
- Comm-D state
- SPI flag

3.4.1.3.4.2 Significance of target record fields.- The significance of most of the fields obtained from the surveillance file can be found in 3.4.6.2. The remaining fields are defined as follows:

- (a) Not Used.
- (b) Range completion - Control bit to indicate a successful range measurement; initialized by transaction preparation and set by transaction update.
- (c) Azimuth completion - Control bit to indicate a successful azimuth measurement; initialized by transaction preparation and set by transaction update.
- (d) Target completion - Control bit to indicate that no further transactions are pending.

- (e) Power-Programming control - Control bit to enable the use of the high-power transmitter mode if required; set by transaction preparation and transaction update.
- (f) Remaining tries - Parameter (0-3,1) regulating number of attempts which will be made to execute the surveillance transaction (per Mode S period) when a target fails to reply; set by transaction preparation and used as a counter by transaction update.
- (g) Comm-B state - A variable defining the state of the pilot-originated Comm-B channel having six values, used and set both by channel management and data link processing, copied into the target record from the active message file by transaction preparation. The state values are the following:

Inactive	- No Comm-B activity pending;
B pending, normal	- B request detected and Comm-B transaction prepared for delivery using normal protocol;
B pending, multisite	- B request detected and Comm-B transaction prepared for delivery using multisite protocol;
B busy	- Comm-B delivery attempted using multisite protocol but channel reserved by another sensor;
Clear B pending, normal	- Comm-B message delivery completed using normal protocol, clear B command prepared but not yet delivered;
Clear B pending, multisite	- Comm-B message delivery completed using multisite protocol, clear B command prepared but not yet delivered.

- (h) Comm-C state - A state variable having five values, used and set both by channel management and data link processing, copied into the target record from the active message file by transaction preparation. The state values are the following:

Inactive	- No uplink ELM activity pending;
C pending, normal	- Uplink ELM transaction prepared using normal protocol but not yet completely delivered;
C pending, multisite	- Uplink ELM transaction prepared using multisite protocol but not yet completely delivered;
Clear C pending, normal	- Uplink ELM completely delivered using normal protocol, clear C command prepared but not yet delivered;

- Clear C pending, multisite - Uplink ELM completely delivered using multisite protocol. clear C command prepared but not yet delivered.
- (i) Comm-D state - A state variable having five values, used and set both by channel management and data link processing, copied into the target record from the active message file by transaction preparation. The state values are the following:
- Inactive - No downlink ELM activity pending;
- D pending, normal - Request to send a downlink ELM detected and transaction prepared using normal protocol but not yet completely delivered;
- D pending, multisite - Request to send a downlink ELM detected and transaction prepared using multisite protocol not yet completely delivered;
- Clear D pending, normal - Downlink ELM completely delivered using normal protocol. Clear D command not yet delivered;
- Clear D pending, multisite - Downlink ELM completely delivered using multisite protocol. Clear D command not yet delivered.
- (j) Acquisition track flag - An indicator signifying whether a target has been fully acquired or not:

Set - Mode S address not yet known and therefore set to all ones (special case);

Reset - Target fully acquired (normal case).

3.4.1.3.4.3 Preparation of the target record. - Transaction preparation shall prepare target records according to the following rules:

- (a) The first 10 fields shall be copied from information in the surveillance file, as stated in 3.4.1.3.4.1.
- (b) Range completion shall be set to incomplete.
- (c) Azimuth completion shall be set to incomplete.
- (d) Target completion shall be set to incomplete.

- (e) The predicted range, as given in the surveillance file for this target, shall be compared to the system parameter PPMINR (power programming range threshold). The power programming control bit shall be set to inhibit if target predicted range does not exceed the value of the system parameter PPMINR, nominally equal to 3000 (0 -16,000, 1,000) range units.
- (f) Remaining tries shall be equated to the system parameter NTRY whose nominal value is 2(0-3, 1).
- (g) The Comm-B, Comm-C, and Comm-D state variables shall be copied from the active message file data block for this target. The active message list is specified in 3.4.7.2.4.
- (h) The values of these state variables shall then be updated according to the following rules, using the values of the primary indicator and the unconnected sensor flag USF as copied in (a) above:

If the primary indicator indicates "yes" (equivalent to sensor priority status PS=P) but the "no communications" flag (3.4.10.3.5.8) is set, this paragraph shall be executed as if the primary indicator indicates "no".

If the primary indicator indicates "no" (equivalent to PS=S), the Comm-B and Comm-D state values shall be changed to "Inactive". If the Comm-C state value is "C pending, normal" or "Clear C pending, normal", it shall be changed to "Inactive". If it is "C pending, multisite", "Inactive", or "Clear C pending, multisite", it shall not be changed.

If the primary indicator indicates "yes" (equivalent to PS=P) and USF = "0" (i.e. connected), all states shall remain unchanged.

If the primary indicator indicates "yes" and USF = "1" (i.e. unconnected), the following state changes shall be made:

"B pending, normal" shall be changed to "B pending, multisite".

"Clear B pending, normal" shall be changed to "B pending, multisite".

"C pending, normal" shall be changed to "C pending, multisite".

"D pending, normal" shall be changed to "D pending, multisite".

All other state values shall remain unchanged.

- (i) It is useful for transaction preparation, roll-call scheduling, and transaction update to define a group of ten 1-bit flags which are collectively called the protocol field. The protocol field shall consist of DL (which was copied into the target record from the surveillance file), and nine additional flags derived from the three variables Comm-B, Comm-C, and Comm-D state, as updated in the previous

step, together with the primary indicator and the USF flag. The additional flags are:

CBN - Clear B, normal protocol
CBM - Clear B, multisite protocol
CCN - Clear C, normal protocol
CCM - Clear C, multisite protocol
CDN - Clear D, normal protocol
CDM - Clear D, multisite protocol
RBM - Reserve B
RCM - Reserve C
RDM - Reserve D

These flags shall be initialized to zero and then set further according to the following rules:

CBN=1 if Comm-B state = Clear B pending, normal.
CBM=1 if Comm-B state = Clear B pending, multisite.
CCN=1 if Comm-C state = Clear C pending, normal.
CCM=1 if Comm-C state = Clear C pending, multisite.
CDN=1 if Comm-D state = Clear D pending, normal.
CDM=1 if Comm-D state = Clear D pending, multisite.
RBM=1 if Comm-B state = B pending, multisite.
RCM=1 either if Comm-C state = C pending, multisite, or
if the primary indicator = yes, USF = 1,
Comm-C state = Clear C pending (normal or
multisite), and there is another uplink
ELM entry in the active message list.
RDM=1 if Comm-D state = D pending, multisite.

3.4.1.3.5 Composition of target transaction blocks.

3.4.1.3.5.1 Composition of standard transaction records. - Every target transaction block shall contain at least one standard transaction record. Standard transaction records shall contain the following information fields defined in this and subsequent subparagraphs:

Priority
Channel Time
Surveillance transaction indicator
Transaction type
Comm-A entry indicator
Comm-B entry indicator
UM request flag (UMF)
Format type (F)
Data-block length (L)

Protocol field	
Altitude/Identity designator (AI)	
Designator Identification* (DI)	
Reply length (RL)	
Comm-B definition* (BDS)	
Ground-to-air data link message* (MA)	} Present for a trans- action containing a Comm-A interrogation
Tactical Message Subfield* (TMS)	

*See Mode S National Standard

The information contained in the first seven items on this list is used by the roll-call scheduling, transaction update, and target list update functions. The remaining items, beginning with format type, are inputs to the standard Mode S interrogation format entries assembled per 3.4.1.5.4.4.1. The message fields, MA and TMS, are present in the standard transaction record if needed, and roll-call scheduling will supply the remaining interrogation fields. Transaction type identifies both interrogation and reply length, and is redundant with data-block length (L) and (when present) reply length (RL).

It is permissible throughout channel management to define the active target list such that the transaction records contain the pre-formatted message fields as required for interrogation scheduling. Also, additional fields may be added to the active target list to enhance channel management processing.

3.4.1.3.5.2 Composition of ELM transaction records - An ELM transaction record shall contain the following information:

- Priority
- Channel time
- Surveillance transaction indicator
- Transaction type
- ELM entry indicator
- Length*
- Format type (F)
- Data-block length (L)
- Reply type for Comm-C Interrogations* (RC)
- Segment number of ground-to-air ELM segment* (NC)
- Ground-to-air ELM segment* (MC)

*See Mode S National Standard

In the case of an uplink ELM transaction, consisting of N message segments, the final three fields of information shall each be replicated N times, each time with information appropriate to the corresponding segment.

In the case of a downlink ELM transaction, an additional field, remaining length, shall be present. Initially, remaining length shall be set equal to the value of length. For a downlink ELM which has been partially received on a previous scan, remaining length will have a smaller value.

Certain fields shall be the same for all ELM transaction records. These fields shall be established by transaction preparation as follows. Transaction preparation shall:

- (a) Set the surveillance transaction indicator to indicate: no,
- (b) Set the format type (F) equal to '1' (i.e non-standard),
- (c) Set the data-block length (L) equal to '1' (i.e. long).

3.4.1.3.5.3 Significance of transaction record fields.- The following list is intended to clarify the meanings of the transaction record fields and indicate the source of their information content.

- (a) Priority - A one-bit variable which establishes transaction priority; set by transaction preparation either to high (priority) or low (normal).
- (b) Channel time - An estimate of channel time required for transaction; used by scheduling and set by transaction preparation, specified as a range unit word (3.4.13.3.2).
- (c) Surveillance transaction indicator - Set to yes by transaction preparation for the first transaction to be executed when a target enters the antenna beam; used by transaction update.
- (d) Transaction type - One bit of this field distinguishes between standard and ELM transactions. The remaining two bits identify types within each of these classes as follows:

Standard transactions -

Surveillance interrogation/surveillance reply.
 Surveillance interrogation/Comm-B reply.
 Comm-A interrogation/surveillance reply.
 Comm-A interrogation/Comm-B reply.

ELM transactions -

Uplink ELM (Multiple Comm-C interrogations/single Comm-D reply).
 Downlink ELM (Single Comm-C interrogation/multiple Comm-D replies).

Transaction type is set by transaction preparation.

- (e) Comm-A entry indicator - An uplink message identifier copied from the active message file by transaction preparation.
- (f) Comm-B entry indicator - A downlink message identifier copied from the active message file by transaction preparation.

- (g) ELM entry indicator - An ELM message identifier copied from the active message file by transaction preparation.
- (h) Length - Number of message segments in an ELM transaction, (1-16, 1).
- (i) Format type - Interrogation format indicator; set by transaction preparation as follows:
 Standard transaction F = '0'
 ELM or acquisition transaction F = '1'
- (j) Data-block length - Indicator of interrogation length; set by transaction preparation as follows:
 Surveillance or acquisition interrogation L = '0'
 Comm-A or Comm-C interrogation L = '1'
- (k) Protocol field - The set of ten flags previously defined (CBN, CBM, CCN, CCM, CDN, CDM, RBM, RCM, RDM, DL); to be set by transaction preparation.
- (l) Altitude/Identity designator - Control bit specifying whether reply is to contain altitude ('0'), or ATCRBS identity ('1'); set by transaction preparation.
- (m) Reply length - Indicator of reply length of a standard transaction; set by transaction preparation as follows:
 Surveillance reply RL = '0'
 Comm-B reply RL = '1'
- (n) Comm-B definition (BDS) - On-board Comm-B message data identifier; copied by transaction preparation from the active message list for transaction preparation for transactions containing a Comm-B reply. This field consists of the two 4-bit subfields BDS1 and BDS2.
- (o) Ground-to-air data link message (MA) - Message text; copied from the active message list by transaction preparation (Comm-A transaction).
- (p) Tactical message subfield (TMS) - A control field needed to support the linked Comm-A protocol; copied from the active message list by transaction preparation (Comm-A transaction).
- (q) Reply type for Comm-C interrogations (RC) - Uplink ELM interrogation type-code field; copied from the active message list by transaction preparation (ELM transaction).
- (r) Segment number of ground-to-air ELM segment (NC) - Uplink ELM message segment number; copied from the active message list by transaction preparation (ELM transaction).

- (s) Ground-to-air ELM segment (MC)- Uplink ELM message text segment; copied from the active message list by transaction preparation (ELM transaction).
- (t) Designator identification (DI) - Serves to define the use of the uplink data field SD.
- (u) UM request flag (UMF) - Indicates that the transaction reply contains a requested Utility Message (UM). It is set by transaction preparation and used by data link processing in interpreting UM.

3.4.1.3.5.4 Structure of the target transaction block.- A target transaction block shall consist of a target record and one or more transaction records. The target transaction block shall be structured in such a way that the target record contains an indicator, called the current transaction indicator, which identifies a single transaction record (of the one or more records in the block). The indicated transaction shall be the next transaction to be scheduled. Transaction preparation shall set this indicator to identify the so-called surveillance transaction. In addition, the target transaction block shall be structured in such a way that it shall be possible to thread through the transaction records, starting with the surveillance transaction, in the order in which they are to be executed, as established by transaction preparation (and specified in 3.4.1.3.6). Each transaction record shall also contain an indicator, or equivalent, which makes it possible to efficiently retrieve the target record of the corresponding target transaction block.

3.4.1.3.6 Preparation of the target transaction blocks.- Transaction preparation shall prepare a target transaction block for each target fetched from the target files under the rules specified in 3.4.1.3.3. Each target transaction block shall contain a target record, prepared by transaction preparation according to the rules and in the form specified in 3.4.1.3.4. Each target transaction block shall contain one or more transaction records, composed in the form specified in 3.4.1.3.5.1 and 3.4.1.3.5.2. The overall structure of the target transaction block shall conform to the formats and rules specified in 3.4.1.3.5. Transaction preparation shall prepare the set of transaction records making up a target transaction block according to the rules set forth in the following steps.

3.4.1.3.6.1 Special case of acquisition track target.- An acquisition track target, distinguished by having its acquisition track flag set and its Mode S address equal to all ones, shall be processed differently from other targets. A single transaction record shall be prepared, containing the following data values:

Priority	- shall be set to 'priority'.
Surveillance transaction indicator	- shall be set to 'yes'.
Data block length (L)	- shall be set to '0'.
Format control (F)	- shall be set to '1'.
Channel time	- shall be set to 'CTSS'
	(see 3.4.1.3.6.4).

No other fields are required, and no further transaction preparation activities shall be performed for acquisition track targets. All other targets shall be processed as described in 3.4.1.3.6.2 through 3.4.1.3.6.10.

3.4.1.3.6.2 Step one.- Transaction preparation shall prepare a standard transaction record and enter it in the target transaction block in such a way that this transaction shall be the first transaction available for execution (see 3.4.1.3.5.4). This is the surveillance transaction for the corresponding target transaction block. Each additional transaction, prepared in accordance with the following steps, shall be entered in the target transaction block in such a way as to insure its availability for execution following the preceding prepared transaction record. Transaction preparation shall assign the following fields in the surveillance transaction record:

F (format)	- shall be set to '0'.
Priority	- shall be set to priority.
Surveillance transaction indicator	- shall be set to yes.
AI (Altitude/Identity designator)	- shall be set to '0'.
Protocol field	- shall be initialized to all zeroes.
UMF (UM request)	- shall be initialized to '0'.
DI (Designator identification)	- shall be initialized to '000'.

The protocol field and DI shall then be further set according to the contents of the protocol field values in the target record using the following procedure:

- (a) If the ten flags in the protocol field (3.4.1.3.4.3, item (1)) of the target record are all zero, terminate the procedure.
- (b) Otherwise, if all of the multisite protocol flags (CBM, CCM, CDM, RBM, RCM, RDM) are zero in the target record and DL=1 (Mode S lockout used), copy the value of DL into the transaction record, reset it in the target record, and terminate the procedure.
- (c) Otherwise, if all of the multisite protocol flags are zero in the target record and DL=0 (Mode S lockout not used), copy the first non-zero flag from the group CBN, CCN and CDN (taken in that order) into the transaction record, reset it in the target record, and terminate.

- (d) Otherwise, if one or more of the multisite protocol flags is not zero and DI=000, copy and reset all non-zero flags (including DL) unless 1) CCM and RCM are both equal to one, or 2) RCM and RDM are both equal to one. In 1), all flags except RCM shall be copied and reset; in 2), all except RDM. If both cases apply, the rule for case 1) shall be followed. In any case, if any flags are copied, DI shall be changed to 001. If RBM, RCM, or RDM are copied, UMF shall be set to 1.
- (e) If RBM=1 has been copied in 3.4.1.3.6.2 item (d), locate the pilot-initiated entry in the Comm-B sublist of the active message (it will have all zeroes in the BDS field) and alter the sublist parameters so that this message will be handled before any other Comm-B entries which may be present.
- (f) Otherwise, if one or more multisite protocol flags are non-zero but DI is not 000, copy and reset the DL flag only.

3.4.1.3.6.3 Step two.- Transaction preparation shall examine the Comm-A sublist of the active message list for this target. If this sublist is empty, transaction preparation shall:

- (a) Enter no information in the Comm-A entry indicator field.
- (b) Set the L bit (data-block length) to '0'.
- (c) Provide no MA field (ground-to-air data link message) or TMS subfield.

If the Comm-A sublist is not empty, transaction preparation shall:

- (a) Copy the entry indicator of the first Comm-A entry into the Comm-A entry indicator field.
- (b) Set the L bit to '1'.
- (c) Provide MA and TMS from the indicated Comm-A entry.
- (d) Provide an indicator which identifies the next Comm-A entry, if present, or indicates that the Comm-A sublist is emptied.

Transaction preparation shall examine the CAP flag in the target record and the Comm-B sublist of the active message list for this target. If the CAP flag is set, transaction preparation shall:

- (a) Set the RL bit to '1'.
- (b) Set the BDS field to BDS1 = '0001', BDS2 = '0000'.

If the CAP flag is not set and the Comm-B sublist is empty, transaction preparation shall:

- (a) Enter no information in the Comm-B entry indicator field.
- (b) Set the RL bit (reply length) to '0'.
- (c) Enter no information in the BDS field.

If the CAP flag is not set and the Comm-B sublist is not empty, transaction preparation shall:

- (a) Examine the values of BDS1 and BDS2 in the first entry of the Comm-B sublist. If these values are all zeroes, signifying a pilot-originated message, and if the Comm-B state value in the target record is "inactive", then this entry in the Comm-B sublist shall be ignored and the procedure repeated with the next entry, if any. Otherwise, the procedure shall be completed with the first entry.
- (b) If BDS2 is all zeroes, skip items (c), (d), and (e) of this procedure and proceed with item (f).
- (c) If BDS2 is not all zeroes, examine the value of DI for this transaction.
- (d) If DI is not all zeroes, set RL=0, enter no information in the Comm-B entry indicator field or the BDS field, and terminate this procedure.
- (e) If DI is all zeroes, set DI='111' and continue.
- (f) Copy the entry indicator of the first Comm-B entry and the BDS value of that entry into the corresponding fields of the transaction record.
- (g) Set the RL bit to '1'.
- (h) Provide an indicator which identifies the next Comm-B entry, if present, or indicates that the Comm-B sublist is emptied.

3.4.1.3.6.4 Step three.- Transaction preparation shall set the transaction type field to one of the four standard transaction types, according to the definition given in 3.4.1.3.5.3, and depending on the interrogation and reply types established in step two.

Transaction preparation shall assign the value of channel time for this and all subsequent standard transactions in the target transaction block according to the following rule:

- (a) If RL = '0', channel time shall be equated to system parameter CTSS.
- (b) If RL = '1', channel time shall be equated to system parameter CTSL.

The parameter CTSS is nominally equal to 2500 (2000 - 4000, 500) range units. The parameter CTSL is nominally equal to 4500 (3500 - 6000, 500) range units.

3.4.1.3.6.5 Step four.- Additional transaction records shall be prepared for this target transaction block, according to the rules specified in this and subsequent steps. In any additional transaction record, transaction preparation shall set the surveillance transaction indicator to "no" and initialize the UMF and DI flags to '0'.

Transaction preparation shall examine the target record prepared for this target transaction block and if the AI bit (ATCRBS identity request) is set to '1', transaction preparation shall prepare a transaction record, with AI = '1', called an A-transaction.

Transaction preparation shall set the priority bit to priority for any A-transaction prepared under these rules. After the preparation of an A-transaction, in response to the above rules, transaction preparation shall set the ATCRBS ID request bit to '0'. This bit shall be reinterpreted, when encountered later by transaction update, as an A-bit flag. The value '0', present in every target record after transaction preparation is completed, shall be understood to enable response to an A-bit in a reply. The value '1' shall inhibit such response, as specified in 3.4.1.6.5.3.4.

A-transaction interrogations and replies may contain Comm-A and Comm-B messages. If the surveillance transaction has not emptied the Comm-A sublist of the active message list, transaction preparation shall include the next available Comm-A message text in the MA field of the A-transaction record, if such a record is prepared. The Comm-A entry indicator and the L-bit shall be assigned for this transaction record exactly as specified in 3.4.1.3.6.3.

If the Comm-B sublist has not been emptied by the surveillance transaction, the next available Comm-B BDS entry and its entry indicator shall be included in the appropriate fields, and the RL bit set to '1', in the A-transaction record, if such a record is prepared. If BDS2 is not all zeroes in such a record, DI shall be set to '111'. As in 3.4.1.3.6.3, however, a pilot-initiated Comm-B (BDS1 and BDS2 all zeroes) shall be omitted if the Comm-B state=inactive. If the CAP flag was set and not handled in the surveillance transaction, it shall be eligible here. Whenever a Comm-A message or Comm-B message request is included in any transaction, transaction preparation shall update the next entry indicators of the Comm-A and Comm-B sublists, as specified in 3.4.1.3.6.3.

If an A-transaction record is prepared, transaction preparation shall assign the appropriate transaction type and channel time to the records, according to the rules specified in 3.4.1.3.6.4.

3.4.1.3.6.6 Step five.- If the implementation of the four steps previously specified has not emptied both the Comm-A sublist and the Comm-B sublist of the active message list, transaction preparation shall prepare a number of standard transaction records sufficient to empty these sublists by the inclusion of Comm-A message texts and Comm-B message requests. (As before, a pilot-originated Comm-B message will be passed over if the Comm-B State=inactive). In preparing each additional standard transaction record, transaction preparation shall:

- (a) Set the priority bit to priority if either the Comm-A message, or the Comm-B message request, included in the transaction record, is designated high-priority; otherwise, the transaction priority shall be set to normal. The determination of Comm-A or Comm-B message priority shall be made using only the high-order bit of the priority field present in the sublist entry. If this bit is equal to one, the message is high-priority; otherwise, normal. (This procedure maps the multi-level priority structure supplied by data link users into the two levels used by channel management.)

- (b) Assign transaction type, the L-bit, the RL bit, and the channel time field according to the presence or absence of Comm-A and Comm-B messages and the rules specified in 3.4.1.3.6.3 with changes as noted below.
- (c) Set the AI bit to '0'.
- (d) Initialize DI to '000' and UMF to '0'. Note that DI will be further set to '111' in a Comm-B Transaction with EDS2 ≠ '0000'.
- (e) If CAP was set and not handled in a previous transaction, a transaction shall be prepared with RL = '1', BDS1 = '0001', and BDS2 = '0000'. This transaction may carry a Comm-A uplink.

When all transactions needed to service the Comm-A and Comm-B sublists and the CAP flag have been prepared, transaction records pointers shall be modified, if necessary, to achieve the following sequence:

- (a) The surveillance transaction (with Comm-A or Comm-B or both);
- (b) Any additional transactions carrying high-priority Comm-A or Comm-B messages, or both (the first of which may be an A-transaction);
- (c) Any additional transactions carrying low-priority Comm-A or Comm-B messages, or both.

3.4.1.3.6.7 Step six.- If transactions have been created by steps four and five, transaction preparation shall prepare a protocol field for each of them, in the order in which they have been created.

Each protocol field shall be initially set to all zeroes, and shall then be modified according to the procedures (a) through (f) in step one (3.4.1.3.6.2). Note that the protocol flag values in the target record which are used in these procedures will have been modified by step one. Each successive use of the procedures will result in fewer non-zero flags remaining in the target record.

If any transaction with priority = "normal" now has either CBN, RCM or CCN equal to 1, its priority shall be changed to "high". The purpose of this assignment is to ensure that readout of a new pilot-initiated Comm-B or uplink ELM message does not precede a pending clearing or multisite reservation of the corresponding channel.

3.4.1.3.6.8 Step seven.- If the protocol field in the target record is now all zeroes, this step shall be omitted. Otherwise, transaction preparation shall prepare an additional transaction. In this transaction, the following values shall be entered:

F = 0
L = 0
RL = 0
AI = 0
Priority = normal
UMF = 0 initially
DI = 000 initially

The protocol field shall be determined as in step six. Following the preparation of this transaction, step seven shall be repeated as many times as necessary until the protocol field in the target record is all zeroes.

If any transaction with priority = "normal" now has either CBN, RCM or CCN equal to 1, its priority shall be changed to "high". The purpose of this assignment is to ensure that readout of a new pilot-initiated Comm-B or uplink ELM message does not precede a pending clearing or multisite reservation of the corresponding channel.

3.4.1.3.6.9 Step eight. - If both the Comm-C and the Comm-D state values equal "inactive", transaction preparation shall make suitable indication that the last standard transaction record has completed the target block, and the remainder of this step shall be omitted. Otherwise, transaction preparation shall examine the ELM sublist of the active message list for the target whose transaction block is in preparation, to determine if there are any ELM transactions eligible for processing. An uplink ELM shall be eligible if it is the first uplink ELM present in the sublist and Comm-C state value does not equal "inactive". A downlink ELM shall be eligible if it is present in the sublist and the Comm-D state value does not equal "inactive". If there are no eligible transactions, transaction preparation shall make suitable indication that the last standard transaction record has completed the target block. Otherwise, an ELM transaction record shall be prepared for each eligible ELM transaction, according to the rules specified herein. An uplink ELM transaction record, if present, shall be arranged for execution before a downlink ELM transaction record, if present.

Both uplink and downlink ELM transactions may consist of only one message segment. Single segment ELM transactions are uniquely identified by length, as specified in 3.4.1.3.5.3, and they will be treated just like standard transactions by roll-call scheduling.

In preparing an ELM transaction record, transaction preparation shall:

- (a) Assign the length field equal to the length field of the corresponding ELM sublist entry.
- (b) Copy the ELM entry indicator from the ELM sublist into the ELM entry indicator field.
- (c) Copy RC, NC, and the message segment text from the ELM sublist into the corresponding transaction record fields.

- (d) Assign transaction type according to the definitions specified in 3.4.1.3.5.3.
- (e) For an uplink ELM, assign the priority indicator to "normal" or "priority" according to the high-order bit of the user-supplied value of priority (as in step five). For a downlink ELM, set this indicator to "normal".

Note that an N-segment uplink ELM will have a transaction record with its RC, NC, and MC fields each replicated N times.

Transaction preparation shall assign the value CTSL to the channel time field of any uplink ELM or single-segment downlink ELM transaction record. Transaction preparation shall make no assignment of channel time for a multiple-segment downlink transaction. Channel time assignments for multiple-segment ELM transactions are not direct estimates of expected channel occupancy, and are used by roll-call scheduling in a special way.

3.4.1.3.6.10 Order of transaction records.- Following creation of all transaction records required by steps one through eight, transaction record pointers shall be modified, if necessary, to achieve the following sequence:

- (a) A surveillance transaction (exactly one will be present).
- (b) Other standard transactions with high priority (any number may be present).
- (c) An uplink ELM with high priority (at most one).
- (d) Standard transactions with normal priority (any number).
- (e) An uplink ELM with normal priority (at most one).
- (f) A downlink ELM (at most one).

3.4.1.4 Target list update.

3.4.1.4.1 Inputs.- Target list update shall accept enabling commands from channel control. Each enabling command shall contain a cutoff azimuth for the use of target list update. Upon receipt of this enabling command, target list update shall fetch the set of target transaction blocks prepared by transaction preparation during its previous period of activity. The set of target transaction blocks may be empty if, responding to its previous enabling command, transaction preparation found no new targets to fetch. The interface between transaction preparation and target list update, shown in fig. 3.4.1-1 as the transaction buffer, shall be organized and managed in such a way that with each enabling command, target list update is given as input all the target transaction blocks, or an empty set indicator, available as output from the last operation of transaction preparation.

3.4.1.4.2 Outputs.- The major outputs of target list update shall be:

- (a) An updated active target list.
- (b) A new released target list.

The active target list consists of the target transaction blocks of targets currently within the antenna beam and with pending transactions. The released target list consists of the target transaction blocks of targets which have either left the antenna beam or have no further pending transactions. The structure, composition, formation or updating of these lists is specified in this subparagraph, 3.4.1.4.

The only other output of target list update is a notice of completion of its task. When its assigned task is completed, target list update shall send notice of task completion to channel control. If the active target list is empty after target list update, then this condition shall be reported in the target completion notice.

3.4.1.4.3 The active target list. - Channel management shall maintain a list of targets currently in the antenna beam, with transactions prepared and not yet fully executed, called the active target list. The active target list shall consist of a list header and a set of target transaction blocks.

3.4.1.4.3.1 Composition of the active target header. - The active target list header shall contain the following fields of information:

- (a) First target indicator
- (b) First target range delay
- (c) Priority channel time for standard and single segment uplink ELM transactions
- (d) Priority channel time for multiple segment ELM uplink transactions
- (e) Normal channel time for standard and single segment uplink and downlink ELM transactions
- (f) Normal channel time for multiple segment ELM uplink transactions

The significance of these fields is specified in 3.4.1.4.3.3.

Entries (a) to (f) above may be stored in another suitable file for use by channel management.

3.4.1.4.3.2 Structure of the active target list. - The active target list shall consist of a list header and an ordered set of target transaction blocks. The target transaction blocks shall be ordered by the value of the range delay contained in each target transaction block header (i.e., the target record). The ordering shall be in approximately decreasing order of range delay, as specified in 3.4.1.4.5.3. The active target list shall be structured in such a way that it shall be possible to thread through the list in the order specified herein, starting with a first target and ending with a last target.

3.4.1.4.3.3 Significance of the active target list header fields. - Active target list header fields shall have the following significance:

- (a) The first target indicator shall provide the location of the target transaction block of the first target on the active target list (if such a pointer is required by the data structure adopted for the active target list) or else indicate empty if the active target list is empty.
- (b) The first target range delay (specified as a range unit word) shall contain the value of range delay contained in the target record of the first target transaction block.
- (c) The first priority channel time (specified as a range unit word) shall be the sum of the channel time values of the current priority transaction records, excluding uplink ELM transactions of two or more incomplete segments.
- (d) The second priority channel time (specified as a range unit word) shall be the sum of the channel time required for the current priority uplink ELM transactions with two or more incomplete segments.
- (e) The first normal channel time (specified as a range unit word) shall be the sum of the channel time values of the current normal transaction records, excluding uplink and downlink ELM transactions of two or more incomplete segments.
- (f) The second normal channel time (specified as a range unit word) shall be the sum of the channel time required for the current normal uplink ELM transactions with two or more incomplete segments remaining.

In these definitions, the current transaction is the next transaction to be executed for each target. The current transaction indicator is set to the surveillance transaction by transaction preparation, and advanced through the set of transaction records by transaction updates, as specified in 3.4.1.6. The channel time sums referred to above are taken from the current transaction records, one term in the sum from each target transaction block whose current transaction record qualifies for inclusion in the sum, according to the above definitions.

The second priority and normal channel times are estimates of the total channel time required to execute the remaining final and non-final segments of ELM uplink transactions with two or more segments remaining to be completed for each priority class. The time required for each of the above transactions shall be added to the appropriate channel time total and shall be computed for each transaction according to the formula:

$$CT = CTSL + 800(N-1)$$

The symbols used in this formula shall have the following meanings:

CT uplink ELM channel time in range units.
CTSL system parameter defined in 3.4.1.3.6.4.
N number of uplink segments which are currently
 incomplete.

If the active target list is empty, only the first target indicator field shall be significant.

3.4.1.4.4 The released target list.- Each time it operates, target list update shall produce a released target list, consisting of a header and a set of target transaction blocks. This list is a major output of channel management, and it shall be available to surveillance processing and data link processing through a suitable interface. The released target list header shall consist solely of an indicator which provides the location of the first target transaction block on the list, if such a pointer is required by the data structure adopted for the released target list. If the released target list is empty, the list header shall indicate empty. The released target list shall be structured in such a way that it shall be possible to thread through the target transaction blocks of the targets on the list. The order of the blocks on this list is not significant. Formation of this list is specified in 3.4.1.4.5.1.

3.4.1.4.5 Operation of target list update.- When enabled by channel control, target list update shall operate to:

- (a) Form a new released target list.
- (b) Update the remaining target transaction blocks.
- (c) Merge the new target transaction blocks into the active target list.
- (d) Update the active target list header.
- (e) Report completion of its task to channel control.

The last subtask has already been specified in 3.4.1.4.2. The remaining subtasks, (a), (b), (c), and (d) above, are specified in this subparagraph. The subtasks are specified separately, although they can be carried out concurrently. Target list update shall be implemented to carry out its assigned subtasks efficiently and concurrently, within an ATRBS/All-Call period. Target list update shall not be required to update the active target list if the time between two successive Mode S periods is less than the nominal ATRBS/All-Call period (2.0 milliseconds).

3.4.1.4.5.1 Formation of the released target list.- Target list update shall remove from the active target list every target transaction block which meets either of the following two criteria:

- (a) The target completion indicator and the range and azimuth completion indicators in the target transaction block header (target record) all indicate that the target is complete;
- (b) the value of the last likely azimuth, found in the same target record, is smaller than the cutoff azimuth included in the target list update enabling command.

The nature of the current transaction indicator, which denotes the next transaction to be executed, was specified in 3.4.1.3.5.4. The cutoff azimuth shall be understood to exceed the last likely azimuth if the former indicates a direction more advanced, in the clockwise sense, than the direction indicated by the latter, by an amount not greater than 180 degrees. After a target transaction block has been removed from the active target list by target list update, that target transaction block shall no longer be encountered when threading through the active target list.

The set of target transaction blocks removed from the active target list by the above rule shall constitute the items of the released target list formed by target list update in its current period of activity. The released target list itself shall be formed by the creation, by target list update, of a released target list header, and a data structure permitting the list items to be accessed in some order.

Transaction update will have set a completion indicator in the transaction record of every successfully executed transaction (see 3.4.1.6). The completion indicator, a single bit, may be added to the transaction record or it may be overwritten on a one-bit field of the transaction record which is no longer needed, such as the priority bit. Whichever option is used, the usage shall be consistent between transaction update and target list update. Target list update must set the completion indicators of all non-executed transactions to incomplete, according to the rules specified in this subparagraph.

Target list update shall set the completion indicator to incomplete in the current transaction record and any succeeding transaction record for each released target transaction block. The structure specified in 3.4.1.3.5.4 for target transaction blocks permits target list update to access the unexecuted transaction records in the order of their intended execution.

Many fields of information in both target records and transaction records are of no significance to the subsequent users of the released target list. This fact may be utilized in restructuring the completed transaction records. The following fields of information, however, shall be preserved by target list update:

(a) Target record fields:

- Mode S address
- Range delay
- Target completion
- Range completion
- Azimuth completion
- ~~Comm~~-B state
- ~~Comm~~-C state
- ~~Comm~~-D state
- Primary indication
- Unconnected sensor flag

(b) Standard transaction record fields:

- Completion indicator
- Transaction type
- ~~Comm~~-A entry indicator
- ~~Comm~~-B entry indicator
- Uplink fields RR, DI
- UM flag
- Protocol field

(c) ELM transaction record fields:

- Completion indicator
- Transaction type
- ELM entry indicator

In addition, target list update shall preserve all reply pointers associated with transaction records by transaction update, as specified in 3.4.1.6.3.

3.4.1.4.5.2 Updating target records.- Target list update shall select, from the target transaction blocks remaining in the active target list, those for which:

- (a) The target completion indicator in the target record indicates "complete", and
- (b) Either one or both of the range or the azimuth completion indicators in the target record indicates "incomplete".

In these target records, target list update shall set the target completion indicator to indicate incomplete. This action is a part of the regulation of reinterrogations to targets. Other parts of this regulation are specified in 3.4.1.6.5.2.

3.4.1.4.5.3 Merging new targets into the active target list.- The active target list, before the operation of target list update, is ordered in approximately decreasing order of the value of each target's range delay. The definition of this approximate ordering is as follows. Let T_1 and T_2 stand for two target transaction blocks on the active target list. Also, let D_1 be the range delay contained in the header of T_1 , while D_2 is the range delay contained in the header of T_2 . If the values D_1 and D_2 satisfy the relation

$$D_2 < D_1 - \text{ALRL},$$

where ALRL is a parameter, then T_2 shall follow T_1 in the active target list order. The value of ALRL shall be 64 (0-256, 32) range units. If D_1 and D_2 satisfy the relation

$$D_1 < D_2 - \text{ALRL},$$

then T_1 shall follow T_2 in the active target list order. If neither of the above relations is satisfied, the order of the transactions may be arbitrarily assigned. The intent of this specification is to facilitate the speedy reestablishment of order when new targets are merged into the active target list. One way to achieve an appropriate ordering of the kind defined here is by the use of an ordering algorithm, with one or more of the low-order bits of the range delay word masked.

The approximate ordering of the active target list is clearly not affected by the removal of target transaction blocks. Target list update shall add the new target transaction blocks to the active target list in such a way that the augmented active target list is approximately ordered in the sense defined above. The specified structure of the active target list shall be maintained by target list update, so that, after the removal of target transaction blocks and also after the addition of new target transaction blocks, the active

target list is properly structured. The active target list is properly structured if it is possible to thread through the target transaction blocks on the list in approximately decreasing order of range delay.

An acceptable way of accomplishing the addition of new target transaction blocks is the technique of first establishing the desired order among the new target transaction blocks, and then merging the new blocks with the existing active target list while preserving the desired order.

The active target list may be range ordered by decreasing range delay or ranged ordered by decreasing range delay divided by two (one way range).

3.4.1.4.5.4 Updating the active target list header. - The process of updating the active target list by removal of target transaction blocks and merging of new blocks, as specified above, will inevitably identify a first target of the updated list. Target list update shall place this first target transaction block in the proper relationship with the active target list header. The location of the first target transaction block shall be entered in the first target indicator. If the updated active target list is empty, the first target indicator shall indicate empty. If the updated active target list is not empty, target list update shall update the remaining active target list header fields, according to the following rules:

- (a) The range delay of the first target transaction block (contained in the target record) shall be entered in the first target range delay field.
- (b) Target list update shall sum the channel time values of the current transaction records of all priority transactions, excluding ELM transactions of two or more incomplete segments, on the active target list. The first priority channel time shall be equated to this sum.
- (c) Target list update shall sum the channel time required for the current priority ELM uplink transactions of two or more incomplete segments according to the formula specified in 3.4.1.4.3.3 and shall assign this value to the second priority channel time field.
- (d) Target list update shall sum the channel time values of the current transaction records of all normal transactions, excluding downlink and uplink ELM transactions of two or more incomplete segments, on the active target list. The first normal channel time shall be equated to this sum.
- (e) Target list update shall sum the channel time required for the current normal ELM uplink transactions of two or more incomplete segments according to the formula specified in 3.4.1.4.3.3, and shall assign this value to the second normal channel time field.

3.4.1.5 Roll-call scheduling.

3.4.1.5.1 Inputs.- Roll-call scheduling shall accept enabling commands from channel control. Each enabling command shall contain a schedule start (SS) time and an available time (AT), as specified in 3.4.1.2.5.

A second input to roll-call scheduling is the active target list, which will have been processed by target list update or transaction update. As specified in 3.4.1.4.3, the active target list is structured in such a way that roll-call scheduling can thread through the target transaction blocks of the targets on the list, encountering targets in approximately decreasing order of range delay. Some targets on this list may have had all prepared transactions executed, with no transactions pending. The completed nature of such a target shall be evidenced to roll-call scheduling by the target completion indicator in that target's target record, as specified in 3.4.1.6.5.3.12. The target record (i.e., the target transaction block header) of a target with one or more pending transactions always contains a current transaction indicator which identifies and locates the transaction record of the pending transaction. Roll-call scheduling can therefore pass through the blocks on the active target list, can pass over completed targets, and can have available for all other targets both the target record and the transaction record of the next transaction to be executed as well as subsequent transactions. For brevity of description, the term "active record list" shall be understood to mean a list containing that portion of the information contained in the active target list which is of direct and immediate use to roll-call scheduling. The active record list shall contain one item for each non-completed target on the active target list. An active record list item shall consist of a target record and the indicated current transaction record for the corresponding target. The active record list is an abstraction, not a file; the concept is used for the concise description of the subset of the records constituting the active target list which are actually used at one time by roll-call scheduling. The items of the active record list shall be visualized as ordered exactly as the corresponding target transaction blocks are ordered on the active target list.

The final input to roll-call scheduling is a set of high-power flags, prepared by transaction update for certain targets in the active target list.

3.4.1.5.2 Outputs.- The major outputs of roll-call scheduling are:

- (a) A list of interrogation control commands.
- (b) A list of reply control commands.

The interrogation control commands produced by roll-call scheduling shall be sent to transmitter/modulation control through the transmission buffer. The reply control commands produced by roll-call scheduling shall be sent to the Mode S reply processor through the same buffer. The release of these commands from the buffer is controlled by channel control.

The remaining output of roll-call scheduling is a completion notice. Upon completion of its assigned task, roll-call scheduling shall send notice of completion to channel control. The completion notice shall contain the schedule end time.

3.4.1.5.3 Allocation.

3.4.1.5.3.1 Principles of allocation.- Roll-call scheduling is responsible for the preparation of a schedule of interrogation and reply listening periods which fits within the available time. The process of selecting the targets, from among those represented on the active record list, which will be included in the output schedule is called allocation. The preparation of a schedule for the qualifying targets is called scheduling. For the first schedule of a Mode S period, allocation is accomplished as follows:

- (a) A preliminary computation, called the allocation computation, is carried out before scheduling begins.
- (b) A target selection process is then carried out, concurrently with scheduling itself.
- (c) An allocation computation for the next schedule, called a predicted allocation, is then carried out.

For each subsequent schedule within a Mode S period, step (a) is omitted, and steps (b) and (c) are performed. As input to step (b), the previously calculated result of step (c) is used.

In order to specify the rules of allocation concisely, it is expedient to introduce some new definitions.

For allocation purposes, transactions fall into five distinct classes, which shall have the following significance:

- (a) Class one consists of priority transactions other than multi-segment ELM's. All class one transactions are priority standard transactions or single-segment priority uplink ELM transactions.
- (b) Class two consists of priority uplink ELM transactions having two or more segments.

- (c) Class three consists of normal (i.e., nonpriority) standard transactions and single-segment normal ELM transactions, either uplink or downlink.
- (d) Class four consists of normal uplink ELM transactions consisting of two or more segments.
- (e) Class five consists of downlink ELM transactions consisting of two or more segments.

It should be observed that the two priority channel times and two normal channel times contained in the active target list header correspond to the sums of the channel time values of the class one, two, three, and four transactions, respectively, of the targets on the active record list.

An output of the allocation computation, specified in 3.4.1.5.3, is an allocation level, ranging from zero through five. The significance of these levels is as follows:

- (a) Level zero: There is insufficient available time for any further roll-call schedule, or else there are no targets with pending transactions on the active target list.
- (b) Level one: There is available time for some or all class one transactions and no more.
- (c) Level two: There is available time for all class one and some or all class two transactions, and no more.
- (d) Level three: There is available time for all class one and class two transactions, and for some or all class three transactions, and no more.
- (e) Level four: There is available time for all class one, class two and class three transactions, and for some or all class four transactions, and no more.
- (f) Level five: There is available time for all class one, class two, class three and class four transactions, and for some or all class five transactions.

Any level except level zero may have one class partially qualified for scheduling. The qualification of individual targets in this class is based upon the remaining output of the allocation computation, the so-called residual time.

3.4.1.5.3.2 The allocation computation.- If there are no targets with pending transactions on the active target list, roll-call scheduling shall set the allocated level to zero; otherwise roll-call scheduling shall compute an overhead time, according to the formula:

$$OT = RD + OTP.$$

The symbols in this formula shall have the following meanings:

OT	Overhead time
RD	First target range delay, found in the active target list header
OTP	System parameter, 1000 (0 - 5000, 1000) range units

Roll-call scheduling shall next compute a residual time, according to the formula

$$RT = AT - OT.$$

The symbols in this formula shall have the following meanings:

RT	Residual time, in range units
AT	Available time, input from channel control, in range units
OT	Overhead time, specified above.

In this and subsequent computations involving available time, due account shall be taken of the overflow indication which may have accompanied the available time value received from channel control.

Roll-call scheduling shall next determine the allocation level according to the following procedure:

- (a) If RT (residual time) is negative or zero, the allocation level shall be set to zero and the procedure shall be terminated.
- (b) If RT does not exceed the first priority channel time, the allocation level shall be set to one and the procedure shall be terminated.
- (c) If RT does exceed the first priority channel time, then that channel time shall be subtracted from RT, and the result redefined as RT. The procedure shall be continued.

- (d) If RT, as redefined above, does not exceed the second priority channel time, the allocation level shall be set to two. The procedure shall then be terminated.
- (e) If RT does exceed the second priority channel time, then that channel time shall be subtracted from RT, and the result redefined as RT. The procedure shall be continued.
- (f) If RT does not exceed the first normal channel time, the allocation level shall be set to three and the procedure terminated.
- (g) If RT does exceed the first normal channel time, then that channel time shall be subtracted from RT, and the results redefined as RT. The procedure shall be continued.
- (h) If RT does not exceed the second normal channel time, the allocation level shall be set to four. The procedure shall then be terminated.
- (i) If RT does exceed the second normal channel time, then that channel time shall be subtracted from RT, and the results redefined as RT. The allocation level shall be set to five and the procedure terminated.

THIS SPACE INTENTIONALLY UNUSED.

3.4.1.5.3.3 Target selection. - For the first schedule of a Mode S period, roll-call scheduling shall select targets for scheduling in accordance with the allocation level just determined. For subsequent schedules, targets shall be selected in accordance with a predicted allocation level, as defined in 3.4.1.5.3.4. In either case, selection shall be performed as follows:

- (a) Level zero: Roll-call scheduling shall send a notice of completion to channel control, indicating that no schedule is output. Channel control shall respond as specified in 3.4.1.2.5.

- (b) Level one: Roll-call scheduling shall designate all transactions except class one transactions as unqualified for scheduling. All class one transactions shall be designated as qualified for scheduling.
- (c) Level two: Roll-call scheduling shall designate any and all class one transactions as qualified for scheduling, and shall designate any and all class three, class four and class five transactions as unqualified for scheduling.

Class two transactions shall be individually selected for scheduling in conjunction with and concurrently with their scheduling by roll call scheduling.

- (d) Level three: Roll-call scheduling shall designate any and all class one and class two transactions on the active record list as qualified for scheduling, and any and all class four and class five transactions as unqualified for scheduling. A class three transaction shall be designated as qualified if RT exceeds the transaction's channel time value. If so, the channel time shall be subtracted from RT, and the result redefined as RT. If not, the transaction shall be designated as unqualified for scheduling.
- (e) Level four: Roll-call scheduling shall designate any and all class one, class two, and class three transactions as qualified for scheduling and any and all class five transactions as unqualified for scheduling. Class four transactions shall be individually selected for scheduling in conjunction with and concurrently with their scheduling by roll call scheduling.
- (f) Level five: Roll-call scheduling shall designate any and all class one, class two, class three, and class four transactions as qualified for scheduling. Class five transactions shall be individually selected for scheduling in conjunction with and concurrently with their scheduling by roll-call scheduling, as specified in 3.4.1.5.4.5.

3.4.1.5.3.4 Next schedule allocation. - Following target selection for the current schedule (either immediately after executing the scheduling function 3.4.1.5.4 or concurrently with it), a predicted allocation level for the next schedule shall be computed. The basis for the prediction shall be the assumption that all transactions included in the current schedule are completed.

To compute the predicted allocation level, the procedures of 3.4.1.5.3.2 shall be followed with the following changes:

- (a) For each target which has qualified for inclusion in the current schedule, the pending transaction shall not be the one indicated by the current transaction indicator but rather the next one listed (if any).
- (b) Updated values shall be used for RD (first target range delay) and AT (available time) to compute an updated value of RT (residual time).
- (c) The rule in (a) shall be followed to compute updated values of first and second priority and first and second normal channel times.

The resulting value of predicted allocation level shall be available for use in target selection for the next schedule.

3.4.1.5.4 Scheduling.

3.4.1.5.4.1 Principles of scheduling.- The sequence of interrogation transmission and reply listening period start times produced by roll-call scheduling, viewed as events on the time line, is called a schedule.

A schedule consists of interrogations addressed to a particular set of targets and expected replies from the same set of targets, in the same order. Within a schedule, the set of interrogations and replies are broken into groups each comprising a string of interrogations followed by a string of replies, if necessary in order to schedule interrogations and replies on a non-overlapping basis. These two strings, the interrogations and replies, constitute a self-contained portion of the schedule which is called a cycle. A schedule consists of an integral number of cycles.

-82-

FAA-E-2716 & AMEND.-2
SCN-11 (Change 17)

3 4 1 5 4 2 - Not Used.

THIS SPACE INTENTIONALLY UNUSED.

3.4.1.5.4.2 (continued) - Not used

THIS SPACE INTENTIONALLY UNUSED.

3.4.1.5.4.3 Composition of the main schedule.

3.4.1.5.4.3.1 Symbol definitions. - The symbols listed below shall be understood to stand for the numerical values defined here when referenced. All values are in range units.

- | | |
|----------------|--|
| (a) ILS = 316 | 56-bit interrogation length (19.75 μ sec) |
| (b) ILL = 540 | 112-bit interrogation length (33.75 μ sec) |
| (c) RLS = 1024 | 56-bit reply length (64 μ sec) |
| (d) RLL = 1920 | 112-bit reply length (120 μ sec) |
| (e) RRP = 2176 | Repetition period of downlink ELM replies (136 μ sec) |
| (f) RDT = 256 | Downlink ELM reply spacing (16 μ sec) |
| (g) TRD = 2124 | Normal transponder reply delay, measured from the beginning of the P1 pulse (132.75 μ sec) |

The length of a downlink ELM transaction shall be denoted by NSEG.

3.4.1.5.4.3.2 Definition of terms and scheduling steps. - The word schedule, used as a verb, shall signify the following two processing steps, with reference to a single target:

- (a) The computation of the interrogation transmission time and the reply listening period start time for the target as parts of a roll-call schedule.
- (b) The preparation of interrogation and reply control commands for the target, including the times referenced in (a) above.

These steps shall be carried out for each target included in the schedule, in the order in which the targets appear in the active record list. Every target which has been qualified or partially qualified for scheduling, according to the rules specified in 3.4.1.5.3, shall be included in the schedule. In addition, targets with current transactions of the multi-segment downlink ELM type and class 2 and 4 uplink ELMs shall be subjected to a test for qualification before scheduling, as specified below in 3.4.1.5.4.5.

The roll-call main schedule produced in accordance with the rules specified herein always consists of a sequence of cycles, as defined in 3.4.1.5.4.1. The preparation of a schedule cycle consists of two logical steps, as follows:

- (a) The scheduling of the first target in the cycle.
- (b) The iterative scheduling of successive targets in the cycle.

The computation steps corresponding to these logical steps are different from one another. The step described as (b) above, always involves fetching a new qualified target and testing to see if it can be included in the cycle under preparation. If such a target cannot be included in the current cycle, as determined from rules specified in 3.4.1.5.4.4.2, then that target shall be scheduled as the first target of the next schedule cycle by roll-call scheduling. The first schedule cycle shall begin with the first qualified target on the active record list.

Roll-call scheduling shall determine a cycle start time and a cycle end time for each schedule cycle. The cycle end time shall be equated to the end of the reply listening period corresponding to the last target included in the cycle. Reply listening period start and end times are computed by roll-call scheduling as each target is scheduled. Roll-call scheduling shall equate the cycle start time to the main schedule start time for the first schedule cycle, and to the cycle end time of the preceding cycle for subsequent schedule cycles.

Roll-call scheduling shall regulate the use of the high power mode of interrogation. The target record in each target transaction block contains a bit, P, which indicates whether or not high power has been requested (by transaction update) for the next transaction for this target.

3.4.1.5.4.4 Preparation of the main schedule in allocation levels one, two, three and four. In allocation levels one, two, three, or four, each target is already either qualified, partially qualified, or unqualified as a result of the allocation computation. No multi-segment downlink ELM transactions will be pending for targets to be included in the schedule. Targets shall be included in the main schedule in accordance with the rules and ordering specified in 3.4.1.5.4.3.2. The scheduling process is carried out in steps, as follows:

3.4.1.5.4.4.1 Step one (First transaction in a cycle). Roll-Call scheduling shall:

- (1) Determine a cycle start time, T. This time shall be determined in accordance with the procedure specified in 3.4.1.5.4.3.2.
- (2) Fetch the first target to be included in the current cycle from the active record list. Obtain the following information from the active record list for this target and assign symbols as shown:

Mode S address	ID
Range delay	RDEL
Range guard	RGD
High-power flag	P (on = 1)

- (5) Assemble the current uplink message, designated MESS, as shown in Table 3.4.1-1, and as detailed below:

- (a) Assign MESS Uplink Format (UF) field bits as follows:

<u>Interrogation Type</u>	<u>UF Bit Value</u>				
	1	2	3	4	5
Mode S-Only All-Call	0	1	0	1	1
Surveillance-Altitude	0	0	1	0	0
Surveillance-Identity	0	0	1	0	1
Comm-A-Altitude	1	0	1	0	0
Comm-A-Identity	1	0	1	0	1
Comm-C (ELM)	1	1	.	.	.

FAA-E-2716 & AMEND.-2
SCN-11 (Change 17)

-86b-

"This page left blank intentionally"

TABLE 3.4.1-1

FIELDS OF MODE S INTERROGATION MESSAGE, MESS

<u>Interrogation Type</u>	<u>Fields</u>
Mode S-Only All-Call (56-bits)	(<u>UF:5</u>)(<u>PR:4</u>)(<u>II:4</u>) (<u>--19 zeroes--</u>)(<u>AP:24</u>)
Surveillance for Altitude (56-bits)	(<u>UF:5</u>) (<u>PC:3</u>) (<u>RR:5</u>) (<u>DI:3</u>) (<u>SD:16</u>) (<u>AP:24</u>)
Surveillance for Identity (56-bits)	(<u>UF:5</u>) (<u>PC:3</u>) (<u>RR:5</u>) (<u>DI:3</u>) (<u>SD:16</u>) (<u>AP:24</u>)
Comm-A for Altitude (112-bits)	(<u>UF:5</u>) (<u>PC:3</u>) (<u>RR:5</u>) (<u>DI:3</u>) (<u>SD:16</u>) (<u>MA:56</u>) (<u>AP:24</u>)
Comm-A for Identity (112-bits)	(<u>UF:5</u>) (<u>PC:3</u>) (<u>RR:5</u>) (<u>DI:3</u>) (<u>SD:16</u>) (<u>MA:56</u>) (<u>AP:24</u>)
Comm-C (ELM)	(<u>II</u>) (<u>RC:2</u>) (<u>NC:4</u>) (<u>MC:80</u>) (<u>AP:24</u>)

Where (see Mode S National Standard for significance and definition of subfields):

AP = Address/Parity	PC = Protocol
DI = Designator Identification	PR = Probability of Reply
II = Interrogator Ident.	RC = Reply control
MA = Message, Comm-A	RR = Reply Request
MC = Message, Comm-C	SD = Special Designator
NC = C-Segment No.	UF = Uplink Format

Assigned fields are shown thus: (), the number after ":" indicating the number of bits used.

- (b) Assign MESS protocol (PC) field bits according to the values of certain transaction record protocol flag values, as follows:

<u>CBN</u>	<u>CCN</u>	<u>CDN</u>	<u>DL</u>	<u>PC Bit Values</u>		
				<u>6</u>	<u>7</u>	<u>8</u>
1	0	0	-	1	0	0
0	1	0	-	1	0	1
0	0	1	-	1	1	0
0	0	0	0	0	0	0
0	0	0	1	0	0	1

If, however, DL=1 and a global parameter is set indicating that the site-addressed lockout mode is in effect, the preceding table shall be used as if DL were set to 0. If this case applies and DI=000, DI shall be changed to 001.

- (c) Assign MESS Reply Request (RR) field bits as follows:

<u>RL</u>	<u>BDS1</u>	<u>RR bit values:</u>				
		<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>
0	-	0	0	0	0	0
1	X ₁ X ₂ X ₃ X ₄	1	X ₁	X ₂	X ₃	X ₄

- (d) Assign MESS Special Designator Data (SD) field bits, numbered 17-32, as follows:

- (i) Regardless of the value of the DI, SD shall contain the subfield IIS (bits 17-20). Rules for setting IIS are given in (v) below, to be executed after the setting of the other SD subfields as defined in (ii) through (iv).
- (ii) If DI=000, and L=0, the remainder of SD is not used (set to all zeroes). If DI=000 and L=1 (Comm-A), DI shall be changed to 001 and the procedure of (iii) followed.
- (iii) If DI=001, SD contains the subfields MBS (bits 21-22), MES (bits 23-25), LOS (bit 26) RSS (bits 27-28), and TMS (bits 29-32), as defined in the Mode S National Standard. Each subfield shall be set as follows:

<u>MBS:</u>	<u>Protocol Flags</u>		<u>MBS</u>	
	<u>RBM</u>	<u>CBM</u>	<u>21</u>	<u>22</u>
	0	0	0	0
	1	0	0	1
	0	1	1	0

MES:	Protocol Flags				MES		
	RCM	CCM	RDM	CDM	23	24	25
	0	0	0	0	0	0	0
	1	0	0	0	0	0	1
	0	1	0	0	0	1	0
	0	0	1	0	0	1	1
	0	0	0	1	1	0	0
	1	0	0	1	1	0	1
	0	1	1	0	1	1	0
	0	1	0	1	1	1	1

LOS shall be set to 1 if a global parameter is set indicating that the site-addressed lockout mode is in effect; otherwise LOS=0.

RSS:	Protocol Flags			RSS	
	RBM	RCM	RDM	27	28
	0	0	0	0	0
	1	0	0	0	1
	0	1	0	1	0
	0	0	1	1	1

TMS shall be set to all zeroes if L=0. If L=1, TMS shall be set equal to the value of the TMS field stored in the transaction record (3.4.1.3.5.1).

- (iv) If DI = 111, SD contains the subfields RRS (bits 21-24), LOS (bit 26), TMS (bits 29-32), and spares in bits 25, 27, and 28.

RRS shall be set equal to the value of BDS2. LOS and TMS shall be set as in (iii) above.

- (v) Setting of the IIS field shall depend on the value of a site-adaptable global parameter defined for this purpose, as follows:

Global Parameter	DI Value	IIS (Bits 17-20)
1	All values	4-bit sensor identity code
0	000	All zeroes
0	001	All zeroes if all SD subfields other than TMS are all zeroes; otherwise, sensor ID code
0	111	All zeroes if subfield LOS=0; otherwise, sensor ID code

- (e) Assign MESS Designator Identification (DI) field bits, numbered 14-16, the current value of DI.
- (f) Assign MESS Comm-A Message (MA) field bits numbered 33-88, with the MA data contained in the transaction record.
- (g) Assign MESS Address/Parity (AP) numbered 33-56 (for L=0) or 89-112 (for L=1) in accordance with the Mode S National Standard, using the value of Mode S address in the target record. For the Mode S -Only All-Call, UF=01011, this value shall be all ones.

"This space intentionally unused."

-89b-

FAA-E-2716 & AMEND.-2
SCN-2 (Change 8)

"This page intentionally unused."

- (h) Assign MESS Probability of Reply (PR) field bits, numbered 6-9, according to the value of the system parameter reply probability (3.4.12.8):

<u>Reply Probability</u>	<u>PR</u>			
	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1	0	0	0	0
1/2 (nominal)	0	0	0	1
1/4	0	0	1	0
1/8	0	0	1	1
1/16	0	1	0	0

- (i) Assign MESS Interrogator Identification (II) field bits, numbered 10-13, with the 4-bit identity code assigned to the local sensor.
- (j) Assign each MESS bit numbered 14-32 the value of "0" if the Interrogation Type equals "Mode S-Only All-Call".
- (k) Assign MESS Reply Control (RC) field bits, numbered 3-4, with the RC data corresponding to the appropriate ELM segment contained in the transaction record.
- (l) Assign MESS Number of C-Segment (NC) field bits, numbered 5-8, with the NC data corresponding to the appropriate ELM segment, contained in the transaction record.
- (m) Assign MESS Comm-C Message (MC) field bits, numbered 9-88, with the MC data corresponding to the appropriate ELM segment, contained in the transaction record.
- (6) Prepare an interrogation control block in accordance with the specification in 3.4.2.1, assigning the fields as follows:
- (a) The control block designator shall be set to Mode S roll-call transmission for all interrogations including Mode S-only All-Call interrogations used for stochastic acquisition.
- (b) The length bit (1) shall be set to '0' if the transaction type indicates a 56-bit interrogation, or to '1' if the 112-bit interrogation is indicated.
- (c) The transmitter power control bit shall be set to '0' if P = '0'. The bit shall be set to '1' if P = '1'.
- (d) The interrogation transmission time shall equal T.

- (e) The interrogation message shall equal MESS.
- (f) If the interrogation being prepared is for a non-final segment of an uplink ELM, roll-call scheduling shall proceed as follows, otherwise continue with (7) below:
 - (i) Add the value 800 range units to the interrogation transmission time. The sum shall be denoted SET.
 - (ii) If SET, as defined above, does not exceed schedule limit, the interrogation control command shall be sent to the transmission buffer, T shall be set equal to SET, and the scheduling process shall continue with (5) above.
 - (iii) If SET, as defined above, exceeds schedule limit, the interrogation control command just prepared shall not be output by roll-call scheduling, and the schedule shall terminate. The schedule end time shall be set equal to the current value of T. Roll-call scheduling shall then send notice of completion, including the schedule end time, to channel control.
- (7) If the interrogation is not a final uplink ELM, then prepare a pair of receiver control blocks in accordance with the specification in 3.4.2.1.
 - (a) Set Mode S Reply Process enable of the first block to '1' and of the second block to '0'.
 - (b) Set ATCRBS Reply Processor enable for both blocks to '0'.
 - (c) Set the Mode S All-Call indicator of the first block to '1'.
 - (d) Set the Mode S expected message length of the first block to '0' for a 56 bit message and to '1' for a 112 bit message.
 - (e) Set the time the command is to take effect for the first block to $L = T + RDEL$.
 - (f) Set the time the command is to take effect for the second block to $T + RDEL + RGD$.
 - (g) Set for both blocks the Expected target address to ID if not a Mode S only all call interrogation, or to the 4-bit identity code of the sensor if a Mode S only all call interrogation.
 - (h) Set for both blocks the Mode S only all call indicator to '1'.
- (8) Determine whether the scheduling time limit has been reached as follows:
 - (a) Establish a cycle test time, by equating it to the current value of L.
 - (b) Compute the sum of the quantities RGD and REPL.

- (c) Add the sum computed in (b) above to the current value of L.
 - (d) Assign the value of the sum computed in (c) above to the variable SET.
 - (e) Compare the value of SET obtained in (d) above to the schedule limit.
- (9) Take the following action based on the computed value of SET:

If SET exceeds the schedule limit as determined in (e) above, the present interrogation shall not be qualified for scheduling, and the schedule shall terminate. The schedule end time shall be equated to the current value of T. Roll-call scheduling shall send notice of completion, including the schedule end time, to channel control. If SET does not exceed the schedule limit, roll-call scheduling shall:

- (a) Send the interrogation control command to the transmission buffer and set the interrogation test time equal to the sum of T and INTL.
- (b) Send the corresponding reply control command to the transmission buffer.
- (c) Proceed with the preparation of the current cycle, as specified in 3.4.1.5.4.4.2.

3.4.1.5.4.4.2 Step two (Subsequent transactions in a cycle). - Roll-call scheduling shall fetch the next target on the active record list to be included in the schedule. If there are no further targets to be scheduled, roll-call scheduling shall equate schedule end time to SET and send notice of completion, including the schedule end time, to channel control.

If further targets remain to be scheduled, roll-call scheduling shall assign values to the following quantities, from information contained in the appropriate target record and current transaction record:

- (a) ID
- (b) RDEL
- (c) RGD
- (d) (not used)
- (e) P
- (f) INTL
- (g) REPL
- (h) MESS

The definition and rules of assignment of these quantities shall be as specified in 3.4.1.5.4.4.1.

If the transaction being scheduled is a class 2 or class 4 uplink ELM, and RT is greater than zero, then set RT equal to the current value of RT minus CTSL. If RT is less than zero, then the transaction is not qualified for scheduling and the scheduling process shall proceed. If RT is greater than zero, k shall be set equal to the integer value of RT divided by 800. If k is less than the remaining length, then k non-final segments shall be qualified for scheduling and RT set to zero. If k is greater than the remaining length, then all pending non-final segments for the current transaction are qualified for scheduling and RT shall be reset according to the following formula:

$$RT = RT - (\text{remaining length} * 800)$$

If the interrogation currently being scheduled is a non-final segment of an uplink ELM transaction, roll-call scheduling shall then:

- (a) Assign the interrogation time (T) equal to the current value of interrogation test time.
- (b) Reset interrogation test time by adding 800 range units to the value used in (a) above.
- (c) If the current value of interrogation test time exceeds cycle test time, proceed as follows:
 - (1) Exclude the present interrogation from the cycle under preparation.
 - (2) Assign the cycle end time, by equating it to the value of SET.
 - (3) Assign the next cycle start time, according to the rule specified in 3.4.1.5.4.3.2.
 - (4) Schedule the present interrogation as the first interrogation of the new cycle, exactly as specified in 3.4.1.5.4.4.1.
- (d) If the current value of interrogation test time does not exceed cycle test time, proceed as follows:
 - (1) Prepare an interrogation control command, using the current value of T.
 - (2) Send the interrogation control command to the transmission buffer.
 - (3) Continue processing the current uplink ELM transaction's non-final segments with step (a) above.

If the interrogation currently being scheduled is for a standard transaction or for the final segment of an uplink ELM, roll-call scheduling shall:

- (a) Enter the current value of SET into the variable L.
- (b) Subtract RDEL from L and enter the result into the variable T.

- (c) If the current value of T is less than the interrogation test time, indicating an interrogation overlap, proceed as follows:
 - (1) Reset T equal to the current value of interrogation test time.
 - (2) Reset L equal to the sum of T, as redefined in (1) above, and RDEL.
- (d) Calculate the sum of INTL and T and compare the sum to the cycle test time.

If the sum of INTL and T exceeds the cycle test time, roll-call scheduling shall:

- (a) Exclude the present interrogation and reply from the cycle under preparation.
- (b) Assign the cycle end time, by equating it to the value of SET.
- (c) Assign the next cycle start time, according to the rule specified in 3.4.1.5.4.3.2.
- (d) Schedule the present interrogation and reply as the first target of the new cycle, exactly as specified in 3.4.1.5.4.4.1.

If the value of the cycle test time is not exceeded by the sum of T and INTL, as computed in the specification above, roll-call scheduling shall proceed with the inclusion of the present transaction in the cycle under preparation. The interrogation test time shall be equated to the sum of T and INTL. The variable SET shall be equated to the value of the sum ($L + RGD + REPL$), by roll-call scheduling.

Roll-call scheduling shall prepare interrogation control and reply control commands for this transaction, using the current values of T and L.

Command preparation shall be exactly as specified in 3.4.1.5.4.4.1. The duration of the schedule, given the inclusion of the present transaction, shall be tested against the schedule limit, and either the commands executed or the schedule terminated. If the schedule is terminated, schedule end time shall equal the current value of L which is the former value of SET.

If the schedule is not terminated under the above rules, roll-call scheduling shall repeat step two, specified herein.

3.4.1.5.4.4.3 Step three. - Roll-call scheduling shall repeatedly execute step two, specified in 3.4.1.5.4.4.2, until the targets to be included in the schedule are exhausted. Termination of scheduling activity shall be exactly as specified in 3.4.1.5.4.4.2, under the circumstance of exhaustion of targets.

3.4.1.5.4.5 Preparation of a main schedule in allocation level five.- Schedule preparation of this allocation level differs from that specified in 3.4.1.5.4.4 only in the possible presence of downlink ELM transactions, containing two or more segments, in the active record list. Transactions of this kind shall be referred to as DELM transactions.

The main schedule shall be composed and prepared exactly as specified in 3.4.1.5.4.3 and 3.4.1.5.4.4 with the exception of the special treatment of DELM transactions, specified herein.

When roll-call scheduling fetches a DELM transaction for the next target to be scheduled, values of T and L shall be assigned, exactly as in 3.4.1.5.4.4.2. This target shall be tested for inclusion in the current cycle in the same manner as any other target, as specified in 3.4.1.5.4.4.2. If the target must begin a new cycle, the values of T, L and a cycle test time, shall be assigned as in 3.4.1.5.4.4.1.

Roll-call scheduling shall:

- (a) Subtract T from the cycle test time of the current cycle.
- (b) Subtract the difference obtained in (a) above from the residual time, RT, and redefine the result to be RT.

If RT, as redefined above, is negative, roll-call scheduling shall designate this and all subsequent DELM transactions as unqualified for scheduling and proceed as specified in 3.4.1.5.4.4.

If RT, as redefined above, is non-negative, roll-call scheduling shall designate the DELM transaction as partially qualified for scheduling. The number of downlink ELM message segments to be included in the schedule shall be determined as follows. Let M be the largest integer for which the equation

$$M * RRP - RDT \leq RT$$

is true. The quantities RRP and RDT are specified in 3.4.1.5.4.3.1. The number of downlink ELM segments indicated in the target's current transaction record in the remaining length field is denoted NSEG.

If M, determined above, exceeds NSEG, M shall be equated to the value of NSEG. The variable REPL shall be equated to the value of $M * RRP - RDT$, determined above.

If M, as determined above, is zero, roll-call scheduling shall designate this and all subsequent DELM transactions as unqualified for scheduling and proceed as specified in 3.4.1.5.4.4.

If M, as determined above, is positive, roll-call scheduling shall schedule this target exactly as specified in 3.4.1.5.4.4 for any other target with the following exceptions:

- (a) Bits 9 through 24 of the MESS field shall be modified so that the first M bits having the value '1' are unchanged, but any other bits in this field with the value '1' are changed to the value '0'. There should have been exactly NSEG bits with the value '1' before this action. Bits 25 through 88 of the MESS field will always have the value '0' for this type of interrogation.
- (b) The current cycle shall be terminated with the inclusion of a DELM transaction, and the next cycle initiated with a new target fetched from the active record list according to the rules specified in 3.4.1.5.4.4.

The value of RT shall be reduced by REPL and the result redefined as RT. Each DELM transaction shall be processed as specified herein until either:

- (a) No further DELM transactions occur on the active record list.
- (b) All DELM transactions beyond a particular one are designated unqualified for scheduling under the rules specified herein.

It should be noted that DELM transactions are tested for exceeding the schedule limit, just as any other transaction. If a DELM transaction causes a schedule duration to exceed its assigned schedule limit, roll-call scheduling shall:

- (a) Iteratively reduce the integer M by unity.
- (b) At each step, recompute REPL and repeat the test for schedule length.
- (c) Include the DELM transaction with reduced segment number or terminate the schedule with the preceding transaction, depending on the outcome of step (b) above. If the DELM transaction ultimately qualifies for scheduling with a reduced segment number, the MESS field from bit 9 through bit 24 shall be modified exactly as specified above to contain as many bits with the value '1' as there are to be segments in the reply. If the schedule must terminate with the preceding transaction, the DELM transaction shall be designated unqualified for scheduling by roll-call scheduling.

In any case, the value of M actually used in the interrogation (i.e., the number of replies requested), shall be recorded by roll-call scheduling in such a way that this number may be unambiguously associated with the transaction record of this transaction. This information will be used by transaction update.

3.4.1.6 Transaction update.

Note: The following requirements specify that transaction update shall transfer replies from the Mode S reply processor to a storage area. The transfer may be accomplished by hardware or other software functions.

3.4.1.6.1 Inputs.— Transaction update shall accept enabling commands from channel control. The active target list is also used as input by transaction update. Transaction update is concerned with the entire active target list, not the subset defined in 3.4.1.5 as the active record list.

In addition to these inputs, transaction update shall accept Mode S reply data blocks from the Mode S reply processor. In fact, transaction update is responsible for the transfer of these data blocks from the Mode S reply processor into a storage area, or areas, accessible to channel management, surveillance processing and data link processing. This responsibility is specified below. The storage area, or areas, referred to above, shall be denoted reply storage in this subparagraph. A pointer to the location (or locations) of a reply image (or images) in reply storage shall be denoted a reply pointer. Any implementation which makes it possible for one or more images of each Mode S reply data block to be held for processing by channel management, surveillance processing and data link processing will be acceptable. These latter functions are given access to the reply images by the reply pointer, which locates the one or more images of a particular reply.

3.4.1.6.2 Outputs.- Transaction update shall send notice of completion of its assigned task to channel control. Other transaction update outputs are the following:

- (a) An updated active target list. Individual target transaction blocks are modified by transaction update and the active target list header is updated.
- (b) Transaction update provides high power flags for certain targets to roll-call scheduling.
- (c) The reply pointers, defined above, which locate replies for other processing functions, are outputs of transaction update.

3.4.1.6.3 Reply transfer.- Upon receipt of its enabling command, transaction update shall commence to read the active target list. All indicators of qualification, or partial qualification, for scheduling (assigned previously by roll-call scheduling as specified in 3.4.1.5) shall be available to transaction update. Transaction update can therefore thread through the active target list, determine which targets were actually scheduled, and how many replies are to be expected from each transaction.

Transaction update shall direct the transfer of all replies, as they become available from the Mode S reply processor, into reply storage. Transaction update shall provide a reply pointer for each reply and append this pointer to the transaction record corresponding to the reply in the active target list. If multiple reply images are provided in the data transfer operation, the location of every image shall be indicated by the reply pointer. In appending the reply pointer to the transaction record, transaction update may overwrite transaction record fields, so long as the information specified in 3.4.1.4.5.1 is preserved. Downlink ELM transactions with two or more segments will require multiple reply pointers to locate the replies expected in a single schedule. As specified below, uplink and downlink ELM transactions may be repeated one or more times while the target is within beam to complete delivery of multiple segments. When this happens, the same transaction record is used in more than one schedule, hence, transaction update may append reply pointers to a single transaction record more than once. In the case of an uplink ELM, only one reply is expected per schedule. If the transaction is repeated to complete the message delivery, the last reply received will contain all the information of subsequent use to data link processing, although surveillance processing will process all replies. Transaction update shall identify the reply pointer of the last reply received in each uplink ELM transaction in some way recognizable by data link processing.

3.4.1.6.4 Reply appraisal. - In response to every Mode S reply control command, the Mode S reply processor will prepare a Mode S reply data block, even if no reply is received. This activity is specified in 3.4.4. The reply data block contains the following information, more completely specified in 3.4.4.8:

- (a) Data block designator - this field identifies the nature of the data block, and in this case will indicate a Mode S roll-call reply.
- (b) Failure indication (F) - a two bit field which distinguishes four cases, as follows:
 - Valid - an accepted reply with an azimuth measurement.
 - Invalid - a reply with an uncorrectable decoding error.
 - No reply - no reply preamble detected.
 - No azimuth - an accepted reply with no measurement of azimuth.
- (c) Off-boresight monopulse estimate - a monopulse measurement which can be converted to target azimuth relative to boresight. This quantity is represented in a field of eight bits.
- (d) Antenna boresight azimuth - antenna boresight azimuth at the time of measurement, in azimuth units.
- (e) Range correction - the interval from the time the preamble detection window is opened to the time the preamble is actually detected. Preamble detection time is corrected for processing lag, so that it refers to the time of arrival of the leading edge of the first preamble pulse. The sum of the range delay (which determines the reply listening period start time, at which time the preamble listening window is opened) and the range correction equals the sum of the two-way propagation time to the aircraft, the nominal transponder reply delay (132.75 μ s from the arrival at the aircraft of the leading edge of the first interrogation preamble pulse), and any fixed system delay within the sensor.
- (f) Mode S reply message bits - the 32-bit or 88-bit information content of the reply (not including the Mode S address).
- (g) Time-of-day - a coarsely quantized measurement time, not used by transaction update.

A reply is accepted by the Mode S reply processor if the reply preamble is detected in the specified time window, and if the error correction logic produces an acceptable decoding of the message. A monopulse measurement is supplied by the Mode S reply processor if a sufficient number of high-confidence, single-bit monopulse measurements have been obtained.

Transaction update shall determine, from information in the corresponding target record, the exact nature of every reply which is expected. If a reply is of the expected type, the reply is said to conform. Transaction update shall determine the conformance or non-conformance of every reply whose reply failure field indicates valid or no azimuth, by testing each of the possible types, as specified below (see Mode S National Standard for data field definitions):

- (a) All-call reply (to Mode S-Only All-call interrogation): transaction update shall verify that DF=01011.
- (b) Surveillance reply with altitude requested: transaction update shall verify that DF=00100.
- (c) Surveillance reply with ATCRBS ID requested: transaction update shall verify that DF=00101.
- (d) Comm-B reply with altitude requested: transaction update shall verify that DF=10100.
- (e) Comm-B reply with ATCRBS ID requested: transaction update shall verify that DF=10101.
- (f) Comm-D reply in an uplink ELM transaction: transaction update shall verify that DF=11 and KE=1.
- (g) Comm-D reply in a downlink ELM transaction: transaction update shall verify that DF=11 and KE=0.

Transaction update shall declare each expected reply to be accepted, not accepted, or missing, according to the following rules:

- (a) A conforming reply with a reply failure indicator indicating either valid or no azimuth, shall be declared accepted.
- (b) A non-conforming reply or a reply whose failure indicator indicates invalid, shall be declared not accepted.
- (c) A reply whose data block failure indicator indicates no reply shall be declared missing.

Whenever a non-conforming reply is found, transaction update shall append a suitable indication of this fact to the corresponding transaction record.

Only certain fields within the Mode S reply message are utilized by transaction update after conformance testing is completed. These are the following, depending upon reply type:

- (a) All-call: AA (for aircraft address).
- (b) Standard replies: FS (for alert and SPI), UM (for multi-site protocol) and DR (for Comm-B request and TCAS request).
- (c) Comm-D replies in an uplink ELM transaction: MD (for acknowledgment data).
- (d) Comm-D replies in a downlink ELM transaction: ND (for segment number).

3.4.1.6.5 Target transaction block updating.- In accordance with the contents of each reply data block, transaction update shall update the target transaction block of the corresponding target. After making use of the schedule qualification indicators set by roll-call scheduling, transaction update shall destroy or reset them to avoid confusion when roll-call scheduling next operates. The rules specifying further update activity depend upon the acceptance, nonacceptance or absence of the reply, as follows.

3.4.1.6.5.1 Reply not accepted.- Transaction update shall make no change in the target transaction block in the case of a reply which is not accepted.

This behavior shall automatically leave the target on the active target list with its current transaction as a candidate for reinterrogation. No reply pointer shall be appended to the target transaction block in this case.

3.4.1.6.5.2 Reply missing.- Transaction update shall determine the value of the surveillance transaction indicator of the transaction record corresponding to the reply. If the surveillance transaction indicator indicates no, then no change shall be made in the target transaction block. This case is analogous to the case specified in 3.4.1.6.5.1.

If the surveillance transaction indicator indicates yes, transaction update shall determine the value of remaining tries. If remaining tries are positive, transaction update shall:

- (a) Reduce remaining tries by unity.
- (b) Set a high power flag to on, if the power-programming control bit is set to enable; otherwise, the high power flag is not set. The high power flag, when set, shall be made available to roll-call scheduling, associated in an unambiguous way with the target transaction block of the appropriate target.

- (c) Make no further change in the target transaction block.

In the situation just specified, the transaction remains a candidate for reinterrogation, but with the transmitter in the high-power mode. High power is thus established after the first failure.

If the surveillance transaction indicator indicates yes, and remaining tries is found to be equal to zero, transaction update shall:

- (a) Reset remaining tries to the value of the parameter NTRY, specified in 3.4.1.3.4.3.
- (b) Reset the high power flag to off.
- (c) Set the target completion indicator in the target record to indicate complete.

In the situation just specified, no further reinterrogation will occur before the next operation of target list update, since roll-call scheduling will pass this target over along with other completed targets. However, target list update will recognize that range completion indicates incomplete (i.e., no replies have been received from this target in the present scan), and it will change the target completion indicator to incomplete once again. The target will thus be a candidate for as many as $(NTRY + 1)$ reinterrogations after target list update next completes its task. These reinterrogations will begin at low power.

3.4.1.6.5.3 Reply accepted.- If one or more of the conditions described in the following subparagraphs occur, then transaction update shall carry out the specified activity or activities. In every case, it shall be understood that the reply in question has been accepted.

3.4.1.6.5.3.1 Range completion.- If the surveillance transaction indicator indicates yes, transaction update shall set range completion (in the target record) to yes. This will be the first range measurement obtained on this target.

3.4.1.6.5.3.2 Azimuth completion.- If the accepted reply is valid, and the azimuth completion indicator in the target record indicates incomplete, transaction update shall examine the off-boresight monopulse estimate field in the reply data block. Let the sum of this field and the table offset value Δm (3.4.10.3.5.2) be denoted SIG. Transaction update shall compare SIG to two system parameters, MBL, nominally 10(0 -127, 1) and MBH, nominally 245(128 -255, 1), and proceed as follows, depending on the outcome of the comparison:

- (a) If SIG satisfies the inequality

$$\text{SIG} < \text{MBL}$$

this indicates that the target is leaving the beam and is already outside of the monopulse measurement window. In this case, transaction update shall set the azimuth completion indicator to complete and shall determine off-boresight azimuth, θ_{off} , according to the formula

$$\theta_{\text{off}} = -\theta_{\text{half}}$$

where θ_{half} is the system parameter specified in 3.4.1.2.4.

- (b) If SIG satisfies the inequality

$$\text{SIG} > \text{MBH}$$

this indicates that the target is about to come into the beam. In this case, transaction update shall set the target completion indicator to complete. The azimuth completion indicator shall remain: incomplete.

- (c) If SIG satisfies the inequality

$$\text{MBL} < \text{SIG} < \text{MBH},$$

transaction update shall determine off-boresight azimuth, θ_{off} , by entering the off-boresight azimuth lookup table, specified in 3.4.11, using the value of SIG as an index. The azimuth obtained is in azimuth units. Transaction update shall set the azimuth completion indicator to complete.

If either case (a) above, or case (c) above occurs, transaction update shall: compute a value for the last likely azimuth and enter that value in the last likely azimuth field of the target record (overwriting the value placed there by transaction preparation). Last likely azimuth shall be computed according to the formula.

$$\theta_{\text{last}} = \theta_{\text{bore}} + \theta_{\text{off}}$$

In this formula all quantities are in azimuth units and the symbols have the following significance:

θ_{last}	last likely azimuth
θ_{bore}	boresight azimuth (reply data block)
θ_{off}	off boresight azimuth, computed as specified above.

3.4.1.6.5.3.3 All-Call reply.- If an accepted reply is received of the type All-Call (identified by DF=01011), it will refer to a target flagged as "acquisition track". For such a reply, transaction update shall cause the aircraft address (field AA in bits 9-32) to be entered in the Mode S address field of the target record, for use by surveillance processing. No further action shall be taken by transaction update for such acquisition track targets other than marking completion, so paragraphs 3.4.1.6.5.3.4 through 3.4.1.6.5.3.11 do not apply.

3.4.1.6.5.3.4 Alert response.- An alert is reported in the FS field (contained in bits 6-8 of any standard reply) if FS has the value 010, 011, or 100. If one of these FS values is present in the current reply, transaction update shall:

(a) Provide for an A-transaction (a standard transaction with AI = '1', as defined in 3.4.1.3.6.5) as specified herein, unless the A-bit flag is set to '1' in the target record.

(b) Set the A-bit flag to '1' in the target record, to prevent repetition of this activity in the present scan.

In order to provide an A-transaction, transaction update shall examine the transaction record arranged for execution next (i.e., immediately after the current transaction) in the target transaction block, if one is present. If this is a standard transaction, transaction update shall set the AI bit to '1' and priority to 'priority' in this transaction record. Only this next transaction record may be so modified for this target, and if no such standard transaction awaits execution, transaction update shall prepare a transaction record and add it to the target transaction block. The new transaction record shall be added in such a way that it is eligible next for execution, to be followed by the transaction record (if any) it replaces. The current transaction indicator shall indicate this new transaction record. The rules of target transaction block structure, specified in 3.4.1.3.5.4, shall be adhered to. The new transaction record shall be of the standard type, requiring a surveillance interrogation and a surveillance reply. In the new transaction record, priority shall be set to 'priority', channel time shall be equated to the parameter CTSS, specified in 3.4.1.3.6.4, the surveillance transaction indicator shall indicate no, and transaction type shall indicate the specified nature of the transaction. No entry indicators or MA field will be present. The transaction record fields shall be assigned as follows:

F = '0'
 L = '0'
 AI = '1'
 RL = '0'
 Protocol field = all zeroes

UMF = '0'
DI = '000'

The reply field FS also expresses the aircraft SPI. In testing FS for the alert condition, an SPI flag shall be set to '1' in the target record if FS=100 or 101 in any reply; otherwise it shall be set to '0'. This step facilitates transfer of the SPI information.

3.4.1.6.5.3.5 Multi-site protocol response. - If the reply being processed carries multisite protocol information, the UM field (bits 14-19 of a standard reply) shall be examined. This will be the case if the reply corresponds to an interrogation with DI=001 and RSS=00 (RSS is bits 27-28 in the SD field). For this case, exactly one of the three protocol flags RBM, RCM, and RDM will have been set in the transaction record. The following actions shall be taken by transaction update:

- (a) The subfield IDS (bits 18-19, in UM) shall be tested for agreement with the following values:

Protocol Flag	IDS bit values	
	18	19
RBM=1	0	1
RCM=1	1	0
RDM=1	1	1

- (b) If IDS does not contain the value indicated in this table, the remaining steps (c) through (f) of this subparagraph shall be omitted.
- (c) The subfield IIS (bits 14-17, in UM) shall be compared with the 4-bit identity code assigned to the local sensor to see if all bits match.
- (d) If RBM=1, and the IIS code does not match, the Comm-B state shall be changed from "B pending, multisite" to "B busy". If the IIS code matches, the state shall not be changed.
- (e) If RCM=1 and the IIS code matches, no further action shall take place. If RCM=1 and the IIS does not match, the Comm-C state shall be changed from "C pending, multisite" to "inactive", and the pending uplink ELM transaction shall be flagged so that it will not be scheduled again during the present scan.
- (f) If RDM=1 and the IIS code matches, no further action shall take place. If RDM=1 and the IIS does not match, the Comm-D state shall be changed from "D pending, multisite" to "inactive", and transaction update shall inhibit the execution of the Comm-D transaction for the remainder of the beam dwell.

3.4.1.6.5.3.6 TCAS downlink request: - If the field DR has the value 00010 in any standard reply, readout of a TCAS Comm-B message is being requested, and the procedures of this paragraph shall be executed, once per scan only. A DR value of 00011, 00110, or 00111 signals a Comm-B request in addition to a TCAS request. In that case, the procedures of this paragraph shall be executed, if not already done during the current scan, followed by the procedures of 3.4.1.6.5.3.7.

First, checks shall be made to see if a site-adapted global parameter indicates that TCAS service is to be provided, and if the primary indicator indicates yes. If either of these conditions fails, the rest of this paragraph shall be omitted.

Next, a check shall be made to see whether a TCAS Comm-B reply has already been received during the current scan, including the present reply. A TCAS Comm-B is defined by RL=1 and BDS=00110000. If a TCAS Comm-B has been received, the rest of this paragraph shall be omitted.

Otherwise, transaction update shall examine the next transaction to be executed, if any, to see whether it is eligible to carry the TCAS message. A transaction shall be eligible if it is a standard transaction with short reply (F=0, RL=0). Modification of an eligible transaction shall consist of setting the following fields:

RL - 1
BDS1 - 0011, BDS2-0000
Channel Time - CTSL
Priority - high

All other fields shall be unchanged.

If there is no eligible transaction, the response shall be to prepare a new transaction record in such a way that it will be executed before any other remaining transactions for the target. This transaction shall be a short uplink with long reply, with the following parameters:

F - 0
L - 0
AI - 0
RL - 1
BDS1 - 0011, BDS2 - 0000
Protocol field - all zeroes
DI - 000
UMF - 0
Channel time - CTSL
Priority - high.

3.4.1.6.5.3.7 Comm-B request.- There are two types of air-initiated Comm-B requests: pilot and broadcast.

3.4.1.6.5.3.7.1 Pilot Comm-B request.- A request to send a pilot Comm-B message is indicated by a code value of 00001 or 00011 in the DR field (bits 9-13) of any standard reply. Such a code value shall be referred to as a "B-request". Transaction update shall ignore the B-request if the primary indicator in the target record indicates "no" or if the "no communications" flag is set (3.4.10.4.5.8). In the remainder of this subparagraph, it shall be assumed that the primary indicator indicates "yes" the "no communications" flag is not set, and a B-request is present in the reply.

- (a) If the Comm-B state field in the target record indicates "B pending, normal" or "B pending, multisite", the B-request in the present reply shall be ignored. (In this case, the appropriate transaction has been prepared already and is pending later execution).
- (b) If the Comm-B state is "B-busy", the B-request shall be ignored. (In this case, the B-request is being handled by another sensor under the multisite protocol).
- (c) If the Comm-B state is "inactive", transaction update shall change the Comm-B state to "B pending, normal" if the unconnected sensor flag USF is not set. Transaction update shall then modify or prepare a transaction record designed to comply with the B-request, as specified herein.
- (d) If the Comm-B state is "inactive" and the multisite protocol applies (USF=1), transaction update shall first determine whether the UM field of the reply contains data directing the Comm-B message to the local sensor. If the UMF flag is not set to 1, the UM field shall be inspected for the values of IDS (bits 18-19) and IIS (bits 14-17). If IDS=01 (indicating that a Comm-B channel reservation is in effect) and if IIS contains a non-zero value not equal to the 4-bit local sensor ID, then the B-request shall be ignored. Otherwise, transaction update shall change the Comm-B state to indicate B pending, multisite, and shall modify or prepare a transaction record designed to comply with the B-request, as specified herein.
- (e) If the Comm-B state indicates "clear B pending, multisite", further action shall depend on whether clearing of the Comm-B channel was accomplished in the current transaction. If the current interrogation contained protocol flag CBM equal to zero, the channel was not cleared and the B-request shall be ignored. If CBM was equal to one, the channel was cleared. In that case, the Comm-B state shall be changed to indicate "B pending, multisite" or "B pending, Normal", according to the current value of USF, and transaction update shall modify or prepare a transaction record as specified herein. (The transponder is capable of clearing the B-request and replacing it with a new one before replying.)

- (f) If the Comm-B state is "clear B pending, normal", further action shall also depend on whether clearing of the channel was attempted in the current transaction. If the current interrogation contained protocol flag CBN equal to zero, the channel was not cleared and the B request shall be ignored. If CBN was equal to one, the channel may have been cleared or the clearing may have been prevented by another sensor's multisite reservation. In this case, the IDS subfield of the UM field in the current reply shall be examined. If IDS=1, then a Comm-B reservation is in effect and the channel was not cleared; the response shall be to change the Comm-B state to "inactive" and to ignore the B request for the remainder of the scan. If IDS contains any value other than 1, the channel was cleared; the response shall be to set the Comm-B state to "B pending, normal" and to modify or prepare a transaction as specified herein.

Transaction update shall modify or prepare a transaction record, under the circumstances specified above, as follows: To determine if a transaction record is eligible for modification, transaction update shall examine the transaction records, if any, arranged for future execution in the target transaction block. If the Comm-B state, as updated, is "B pending, normal", then a transaction record shall be eligible if it is a standard interrogation with a surveillance reply (F='0' and RL='0'). If the Comm-B state, as updated, is "B pending, multisite", then a transaction record shall be eligible if it is a standard interrogation with a surveillance reply and if, in addition, it has the parameter values DI='000' and UMF='0'.

To modify an eligible transaction, transaction update shall change the channel time field to the value of CTSL, a parameter specified in 3.4.1.3.6.4, and enter a special value in the Comm-B entry indicator field. This special value is denoted here as PILOT, and will be understood by data link processing to identify an air-initiated Comm-B message, expedited by channel management. In the interrogation message, the RL bit shall be changed to '1', and BDS shall be set to all zeroes. If multisite protocol applies, RBM shall be set to equal to '1', DI shall be set to '001', and UMF set to '1'.

If no transaction record is eligible, transaction update shall prepare a suitable transaction record and add it to the target transaction block. The new transaction record shall be added in such a way that it will be eligible for execution after any other standard transaction records already present, and before any normal ELM transaction records in the target transaction block. The rules of target transaction block structure, specified in 3.4.1.3.5.4 shall be adhered to. The new transaction record shall be of the standard type, requiring a surveillance interrogation and a Comm-B reply, and the transaction type field shall so indicate. Transaction update shall set priority to normal, channel time to CTSL, the surveillance transaction indicator to no, and the Comm-B entry indicator to the special value PILOT. The interrogation message parameters shall be assigned as follows in the transaction record.

F	- '0'
L	- '0'
AI	- '0'
RL	- '1'

BDS1 - '0000', BDS2 - '0000'
RBM - 1, DI-001, and UMF-1 if Comm-B state -
"B pending, multisite".
RBM - 0, DI-000, and UMF-0 if Comm-B state -
"B pending, normal".
Remaining protocol field flags - 0.

3.4.1.6.5.3.7.2 Broadcast Comm-B request. - A request to send a broadcast Comm-B message is indicated by a DR code value of 00100 or 00110 (for a broadcast "message 1") or by a value of 00101 or 00111 (for a broadcast "message 2"). Upon receipt of such a request, transaction update shall execute the procedures in the remainder of this paragraph regardless of the values of the primary indicator and the Comm-B state.

First, the message number indicated by the DR code value shall be compared with the previous broadcast message number, as stored in the "broadcast message number" field. This field, which shall have been copied from the surveillance file into the target record by transaction preparation, contains one of three values: "message 1" "message 2", or "no previous broadcast message". If the number of the requested message matches the stored value, no further processing of the request shall take place.

Otherwise, the processing shall continue with the modification of an eligible transaction record or the preparation of a new transaction record to carry the broadcast Comm-B. The rules for modifying or preparing a transaction shall be those given above for the case of a pilot Comm-B, with the following differences:

- (a) In determining eligibility of an existing transaction, the rule that applies when Comm-B state - "B pending, normal" shall be used, regardless of the actual value of Comm-B state.
- (b) The multisite protocol shall not be used, regardless of the value of USF or Comm-B state.
- (c) The Comm-B entry indicator field shall be given a special value indicating "broadcast".

The Comm-B state value shall not be changed.

3.4.1.6.5.3.8 Comm-B replies. - If the primary indicator indicates primary, if a reply is the Comm-B type in a transaction which had the value "pilot" in the entry indicator field, and if the Comm-B state is not "B busy", then transaction update shall:

- (a) Examine the Linked Comm-B subfield (LBS) of the MB field in the reply. LBS is a two-bit subfield located in bits 33 and 34 of the reply (i.e., the first two bits in MB). If LBS contains a non-zero value, the reply is the initial segment of a linked Comm-B message. In that case, the procedures of subparagraph (b) shall be executed and those of (c) through (e) omitted. If LBS contains zero, the reply is an unlinked Comm-B, and the procedures of subparagraph (b) shall be omitted and those of (c) through (e) executed.
- (b) The entry indicator in the transaction record of the reply shall be changed to a special value, denoted here as "linked". One or more additional transaction records shall be modified or prepared to handle the remaining segments of the linked Comm-B message as ground-initiated Comm-B transactions. The rules for modifying or preparing each of these transaction records shall be the same as those of 3.4.1.6.5.3.7.1, except that the normal protocol shall apply (regardless of the value of Comm-B state) and the transactions shall be designated as "linked" rather than "pilot" in each entry indicator field. For each transaction, the value of BDS1 shall be 0000. If the value of LBS in the initial segment (already received) is 11, there shall be three transactions, carrying the BDS2 values 0010, 0011, and 0100 in that order. If the value of the LBS in the initial segment is 10, there shall be two transactions, carrying the BDS2 values 0010 and 0011 in that order. If the value of LBS in the initial segment is 01, there shall be one transaction, carrying the BDS2 value 0010. To preserve the correct sequence of segments of the complete message, channel management shall process these transactions in such a way that they shall always be executed in the order of their entries.
- (c) Change the Comm-B state from "B pending, normal" or "B pending multisite" to "clear B pending, normal" or "clear B pending, multisite", respectively.
- (d) Modify a transaction record, if possible, to carry a clear B command. To determine if a transaction record qualifies for modification, under the circumstance defined above, transaction update shall examine the transaction records, if any, arranged for future execution in the target transaction block. If any standard transactions remain to be executed, following the current transaction whose reply is at hand, transaction update shall test the protocol field of such transactions. If the Comm-B state - "clear B pending, normal", a transaction shall qualify for modification if its protocol field contains all zeroes. If the Comm-B state - "clear B pending, multisite", it shall qualify if DI=000 and UMF=0. The qualifying transaction may be an A-transaction inserted under the rule specified above in 3.4.1.6.5.3.4. Only one transaction record shall be so modified for this target.

Modification shall consist of setting CBN-1 for the normal protocol; CBM-1, DI-001, and UMF-1 shall be set for the multisite protocol.

- (e) If no transaction is found which qualifies for modification, no further action shall be taken.

If the reply is a Comm-B type in a transaction which had the value "pilot" in the entry indicator field, but the Comm-B state is "B-busy", no action shall be taken.

If the reply is a Comm-B type in a transaction which had the value "broadcast" in the entry indicator field, transaction update shall first examine the DR field of the reply. If the DR code indicates a broadcast request, the only action shall be to enter the value of message number indicated by that DR value into the broadcast message number field. If the DR field contains the value 00001 or 00011 (because a pilot Comm-B request has superseded the broadcast), transaction update shall change the entry indicator field of the transaction type to indicate a standard transaction with a short reply (deleting the MB field if necessary), so that Data Link processing shall ignore the Comm-B message. It shall then execute the procedure given in 3.4.1.6.5.3.7.1 for a new air-initiated Comm-B request.

If the reply is a Comm-B type in a transaction which did not have the value "pilot" or "broadcast" in the entry indicator field, it is a ground-initiated or TCAS Comm-B. No action shall be taken unless the reply contains the final segment of a linked Comm-B message. In this case, the procedures of sub-paragraphs (c) through (e) above shall be executed.

3.4.1.6.5.3.9 Clear transactions.- If a reply is accepted and if the corresponding interrogation carried one or more clear commands in either normal or multisite protocol (as signified by any of the flags CBN, CBM, CCN, CCM, CDN or CDM equal to one), then transaction update shall change the comm state variable for each channel thus cleared to "inactive".

This space intentionally unused.

An exception to this rule shall be made for a Comm-B clear (CBN or CBM equal to one) if the reply also contains a B request. In this case, the procedures of 3.4.1.6.5.3.7 shall be followed instead.

A further exception shall be made for a Comm-C clear if any uplink ELM transaction records exist for this aircraft. In this case, the state shall be changed to "C pending, normal" or "C pending, multisite", according to the value of USF.

3.4.1.6.5.3.10 Uplink ELM transaction.- A reply to an uplink ELM interrogation always has KE = '1' and a cumulative technical acknowledgment (subfield TAS, bits 17-32) in the MD field. If the uplink ELM transaction, as originally prepared by data link processing, had M segments, then the first M bits of MD are meaningful, and a '1' in one of these bits signifies transponder acceptance of the corresponding uplink message segment. Bit 17 signifies acceptance of message segment number zero, bit 18 refers to segment one, and so on up to bit 32, which refers to segment fifteen, the largest possible segment number. The transaction record for this ELM, when prepared by transaction preparation the first time the target enters the beam with this ELM pending, will have M replicas of the RC, NC and MC fields, corresponding to the M uplink message segments. Channel management notes successful delivery of message segments as follows. If a reply is accepted with KE = '1', transaction update shall obtain the length field value from the target record. Let this value be denoted by M. Transaction update shall obtain the first M bits of the TAS subfield and indicate delivery of segments accepted by the transponder. Each segment is represented in the transaction record by its RC, NC and MC fields, and the segment number is contained in the NC field, hence transaction update can indicate segment delivery in an unambiguous way. The final uplink segment is identified by its RC code of '10'. If the final segment becomes designated as delivered, transaction update shall change the RC code of an undelivered segment to '10'. The chosen segment shall be the last remaining undelivered segment in the order of their placement in the transaction record. The RC code of this segment will always have been '01'.

It is possible (because of a multisite reservation timeout) that a technical acknowledgement field will contain all zeroes even though some segments had previously been accepted. In this case, the completion indicators for those segments shall be reset so that the entire message, including the initializing segment, will be retransmitted.

Segments marked delivered are ignored by subsequent operation of roll-call scheduling. It is important to note that in case the ELM is not fully delivered in a given scan, data link processing will leave the complete original entry in the ELM list, merely copying the delivery indicators from the completed target transaction block. In the next scan, transaction preparation will prepare a new transaction record still indicating M segments, with fields for the delivered segments, completed with delivery indicators. Only when the message is fully delivered or expired will it be removed from the ELM list by data link processing.

3.4.1.6.5.3.11 Downlink ELM transactions.- A downlink ELM transaction is represented by a transaction record whose length field represents the number of downlink message segments which data link processing has requested. Let this number be denoted by L. Parts of this message may have been received in

previous scans, and M segments remain undelivered, as indicated in the remaining length field. The MC field for this transaction, as prepared by transaction preparation, will contain just M '1' values among the first L bits of the 16-bit subfield SRS, the only significant MC bits in this kind of transaction. Roll-call scheduling may or may not have scheduled all M segments, but will have recorded the number actually scheduled, hence transaction update is informed of the number of expected replies. When replies of this type are accepted, transaction update shall modify the remaining length and MC fields in the transaction record in response to the success of the transaction. Let K replies of this type be accepted for the transaction under discussion. Transaction update shall reduce the remaining length field by the amount K and change K of the bits in the MC field to '0'. The bits changed shall correspond to replies received. Replies received identify their segment number in the ND field, and bit position in MC field correspond to segment numbers in exactly the same manner as described above in 3.4.1.6.5.3.10.

Transaction update shall maintain a running count of the number of replies so far requested during the current scan by roll-call scheduling for each downlink ELM transaction. This count shall be accumulated, regardless of whether or not the requested replies were received. It shall be the responsibility of transaction update that no more than $1.25 \times L$ downlink ELM replies are requested from a given target in any one scan. Let the accumulated number of replies already requested be denoted by N. Let the value of the remaining length field for this transaction be R, after the operation of transaction update. If the sum, $N + R$, exceeds $1.25 \times L$, transaction update shall reduce the number of segments to be scheduled by an amount sufficient to reduce the sum to the greatest integer not exceeding $1.25 \times L$. A corresponding number of bits in the MC field shall be changed from '1' to '0'. The position of the bits changed in the MC field by this action is arbitrary.

3.4.1.6.5.3.12 Current transaction indicator update.- When a reply is accepted which corresponds to a standard transaction or a Mode S-Only All Call, transaction update shall indicate completion of this transaction by means of a suitable indicator, appended to the transaction record. Similarly, transaction update shall indicate completion of an ELM transaction as follows:

- (a) An uplink ELM transaction shall be designated complete if every uplink ELM message segment has been designated delivered by transaction update in response to the present reply.
- (b) A downlink ELM transaction shall be designated complete if the remaining length field has been reduced to zero by transaction update in response to the present reply.

When a current transaction is designated to be complete, under the rules specified above, transaction update shall change the current transaction indicator so that it identifies the next transaction, if any, which is pending execution in the target transaction block. If no such transaction is pending, i.e., if the current transaction record is the final transaction record in the target transaction block, transaction update shall determine the value of the azimuth completion indicator in the target record and proceed as follows:

(a) If the azimuth completion indicator indicates complete, transaction update shall set the target completion indicator to indicate completion of the entire target transaction block.

(b) If the azimuth indicator indicates incomplete, transaction update shall prepare a new transaction record and add it to the target transaction block. The new transaction record shall be added in such a way that it shall be eligible next for execution, and the current transaction indicator shall indicate this new transaction record. The rules of target transaction block structure, specified in 3.4.1.3.5.4, shall be adhered to. The new transaction record shall be of the standard type, specifying a surveillance interrogation and a surveillance reply, and the transaction type field shall so indicate. In the new transaction record, priority shall be set to priority, channel time shall be equated to the parameter CTSS, specified in 3.4.1.3.6.4, and the surveillance transaction indicator shall indicate no. No entry indicators or MA field will be present. The interrogation message bits, represented in the transaction record shall be assigned as follows:

F - '0'
L - '0'
AI - '0'
RL - '0'
Protocol field - all zeroes
UMF - 0
DI - 000

3.4.1.6.6 Active target list header update. - (Not used)

3.4.2 Transmitter/modulator.

3.4.2.1 Interfaces.- The transmitter/modulation control function shall receive a transmission control block from the channel management function for each uplink transmission to be generated. The contents of the transmission control blocks for Mode S and ATCRBS shall be as follows (see fig. 3.4.2-1):

- | | |
|--|----------------------------|
| (a) Time of transmission (range unit word, | 3.4.13.3.2) |
| (b) Transmission type | (3.4.2.1.1) |
| (c) Mode S high/low power mode indicator | |
| (d) Listening window | (3.4.1.2.3.4) |
| (e) Mode S roll-call transmission length | |
| (f) Mode S roll-call message block | (56 or 112 bits) |
| (g) Mode S-Only All-Call reply probability | (Mode S National Standard) |
| (h) Mode S Only All-Call Site ID | (Mode S National Standard) |
| (i) I ² SLS (Improved Interrogation Sidelobe Suppression) indicator | |
| (j) Station time clock | (3.4.13.3) |

Transmitter/modulation control shall receive a transmission control block for each ATCRBS or Mode S transmission (see fig. 3.4.2-1(a) and (b)). The 23 bits of the station time clock shall drive a transmission control register. This register shall be used to compare time of transmission (corresponding to the time of occurrence of P₁) received from the channel management function with the lowest order 16 bits of the station time clock. Transmissions shall be generated based on comparison to the least significant 16 bits of the register. When any ATCRBS, ATCRBS/Mode S, ATCRBS-Only or Mode S-Only All-Call transmission occurs a time control block shall be passed back to channel management containing the most significant 15 bits of the transmission control register at the occurrence of P₁ (fig. 3.4.2-1(c)).

For each ATCRBS, ATCRBS/Mode S, and ATCRBS-only All Call the MCU shall send to the ATCRBS Reply Processor a pulse at the time of the P₃ pulse. The MCU shall also send to the ATCRBS Reply Processor the type of interrogation. A listen window corresponds to enabling and disabling the appropriate reply processor using the Receiver Control Block described in Fig. 3.4.2-1(d). For every interrogation, except non-final uplink ELMs, Channel Management must send to the Reply Processors a message to open a listen window and one to close the listen window. For downlink ELMs it is sufficient to send one message to open the Mode S listen window at the start of the first ELM response and one to close the Mode S listen window at the termination of the last ELM response. Each Receiver Control Message shall contain the information in fig. 3.4.2-1(d).

3.4.2.1.1 Transmission types.- The transmitter/modulator shall be capable of transmitting the following interrogation types:

- | | |
|-------------------------------------|----------------------------|
| (a) ATCRBS (Mode A)/Mode S All-Call | (g) Mode S Short Roll-Call |
| (b) ATCRBS (Mode C)/Mode S All-Call | (h) Mode S Long Roll-Call |
| (c) Military Mode 2 | (i) ATCRBS (Mode A) |
| (d) Mode S-Only All-Call | (j) ATCRBS (Mode B) |
| (e) ATCRBS (Mode A)-only All Call | (k) ATCRBS (Mode C) |
| (f) ATCRBS (Mode C)-only All Call | (l) ATCRBS (Mode D) |

(a) Transmission Control Block - Roll-Call

Control block designator	(3.4.1.5.4.4.1(6))
Mode S high/low power indicator	(3.4.1.5.4.4.1(6))
Mode S roll call transmission length	(3.4.1.5.4.4.1(6))
Time of transmission	(range unit word, 3.4.13.3.2)
Mode S roll-call transmission block	(3.4.1.5.4.4.1(6))

(b) Transmission Control Block - ATCRBS, ATCRBS/Mode S, ATCRBS-only
All Call or Mode S-only All-Call

Control block designator	(3.4.1.5.4.4.1(7))
Transmission type	(3.4.2.1.1)
I ² SLS indicator	
Time of transmission	(range unit word, 3.4.13.3.2)
Listening window	(3.4.1.2.3.4)
Reply probability	(Mode S National Standard)
Site ID	(Mode S National Standard)

(c) Time Control Block - To Channel Management

Time block designator	
Time of transmission	(time unit word, 3.4.13.3.1)

(d) Receiver Control Block

Mode S Reply Processor enable
ATCRBS Reply Processor enable
Mode S All-Call or Mode S Roll-Call Indicator (STC Control)
Mode S expected message length (56 or 112 bits)
Range of target (for determining STC of Mode S Roll-Call)
Time the command is to take effect (range unit word
3.4.13.3.2)
Expected target address
Mode S-only All-Call or ATCRBS/Mode S All-Call indicator

Fig. 3.4.2-1. Control Block Content.

3.4.2.2 Modulator unit.

3.4.2.2.1 Transmission control. - The modulation control unit (MCU) shall receive the input information specified in 3.4.2.1 for each transmission. It shall then compare the state of the station time clock to the specified transmission time using the transmission control register and generate an interrogation.

The time of transmission of P_1 (most significant 15 bits) shall be passed back to the channel management function via the time control block. For each ATCRBS, ATCRBS/Mode S, and ATCRBS-only All-Call the MCU shall send to the ATCRBS Reply Processor a pulse at the time of the P_3 pulse.

When a transmission has been initiated, the MCU shall provide the performance monitoring function with the information defining the type of transmission, the power level indicator, and a synchronization signal indicating that the transmission has occurred (see Section 3.4.10).

3.4.2.2.2 Modulation control.

(a) Pulse Amplitude Modulation (PAM) - The control block designator shall define the required preamble and the selection of a PAM or DPSK modulator. A PAM modulator shall generate the preamble field for Mode S roll-call transmissions (P_1 and P_2) as well as the entire ATCRBS, ATCRBS-only All-Call, or ATCRBS/Mode S All-Call transmission (P_1 , P_3 , and P_4) to be transmitted over the Σ -channel. The spacing of the P_1 - P_2 and P_1 - P_3 pulses is as follows:

Mode-2	P_1 to P_3	5.0 ± 0.1 microseconds
Mode-3A	P_1 to P_3	8.0 ± 0.1 microseconds
Mode-B	P_1 to P_3	17.0 ± 0.1 microseconds
Mode-C	P_1 to P_3	21.0 ± 0.1 microseconds
Mode-D	P_1 to P_3	25.0 ± 0.1 microseconds
SLS	P_1 to P_2	2.0 ± 0.1 microseconds

The characteristics of the PAM signals shall be as specified in the Mode S National Standard.

The SLS PAM pulses transmitted over the omnidirectional antenna channel shall be generated by an auxiliary transmitter. The MCU shall provide that transmitter with gates for the generation of the P_1 and P_2 , and the P_3 pulses.

(b) Differential Phase Shift Keying (DPSK) - A DPSK modulator shall produce the data field for the Mode S roll-call and Mode S-Only All-Call transmissions. The DPSK data block shall be as specified in the Mode S National Standard. A phase reversal of the RF signal shall occur at the beginning of a bit interval representing a binary one while no phase reversal shall represent a binary zero. Each transmitted phase reversal shall occur at a time $N * 0.25 \pm 0.02 \mu s$ ($N \geq 2$) after the sync phase reversal. The characteristics of the DPSK signals shall be as specified in the Mode S National Standard.

(c) All modulation (PAM and DPSK) shall be at low level RF and logic switching points. High energy switching shall not be employed. Frequency multiplication after modulation is not permitted. The modulation circuitry shall be protected against active transmitter device arcing, shorting or other modes of failure.

3.4.2.2.3 Parity encoding of the Mode S message field. - A data field buffer shall receive 56 or 112 bits containing the information content of the Mode S transmission. They shall be converted to a serial bit stream and shifted through a parity encoder. The uplink Mode S messages shall employ systematic encoding generated by the encoding circuit specified in fig. 3.4.2-2. The message to be transmitted shall be shifted through the circuit to produce 24 parity bits which shall be added (modulo 2) to the high order bits of the product of the 24-bit address and the polynomial $G(x)$ as the parity bits emerge sequentially from the encoder. This parity/address field is thus formed at the end of the information field which shall remain unchanged during the encoding process. The encoding circuit is specified by the polynomial:

$$G(x) = \sum_{j=0}^{24} g_j x^j$$

where:

$$\begin{aligned} g_j &= 1 \text{ for } j = 0, 3, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 \\ g_j &= 0 \text{ otherwise.} \end{aligned}$$

The resulting coded information sequence shall produce logic levels which drive the DPSK modulator to produce the RF signals for the data field and synchronization block of the uplink Mode S message.

3.4.2.3 Transmitters. - A primary transmitter shall be used for all main-beam transmissions. SLS control transmissions shall be generated by an auxiliary transmitter. The block diagram of fig. 3.4.2-3 shows the placement of transmitter functions in relation to the other RF components. The sensor RF port, marked in figure 3.4.2-3, constitutes the interface point between the sensor and the antenna system. The sensor RF port, which shall be clearly identified on the equipment, is used as the reference point in power level

$a = \begin{cases} '1' & \text{FOR INFORMATION} \\ '0' & \text{FOR ADDRESS} \end{cases}$

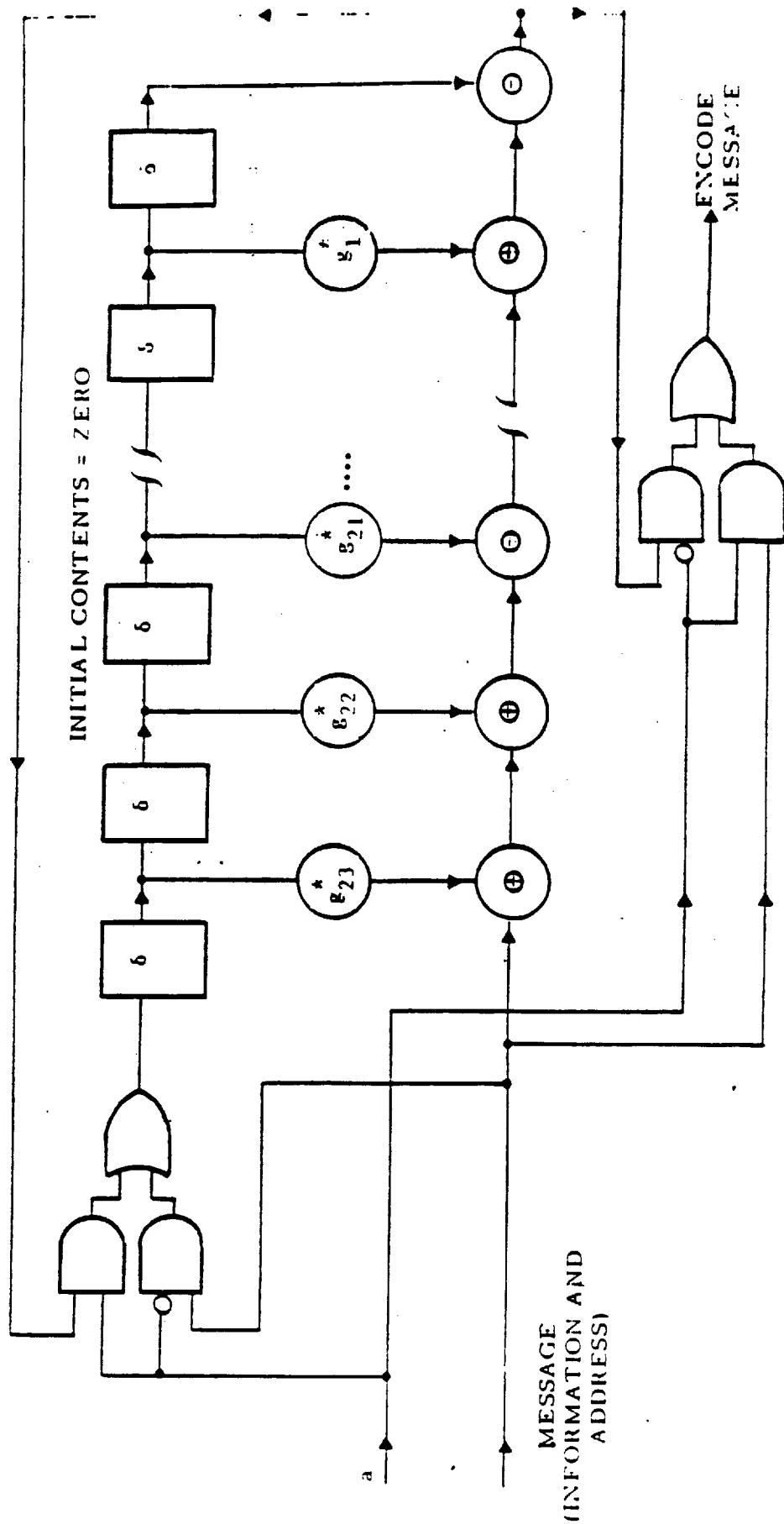


FIGURE 3.4.2-2
UPLINK ENCODER

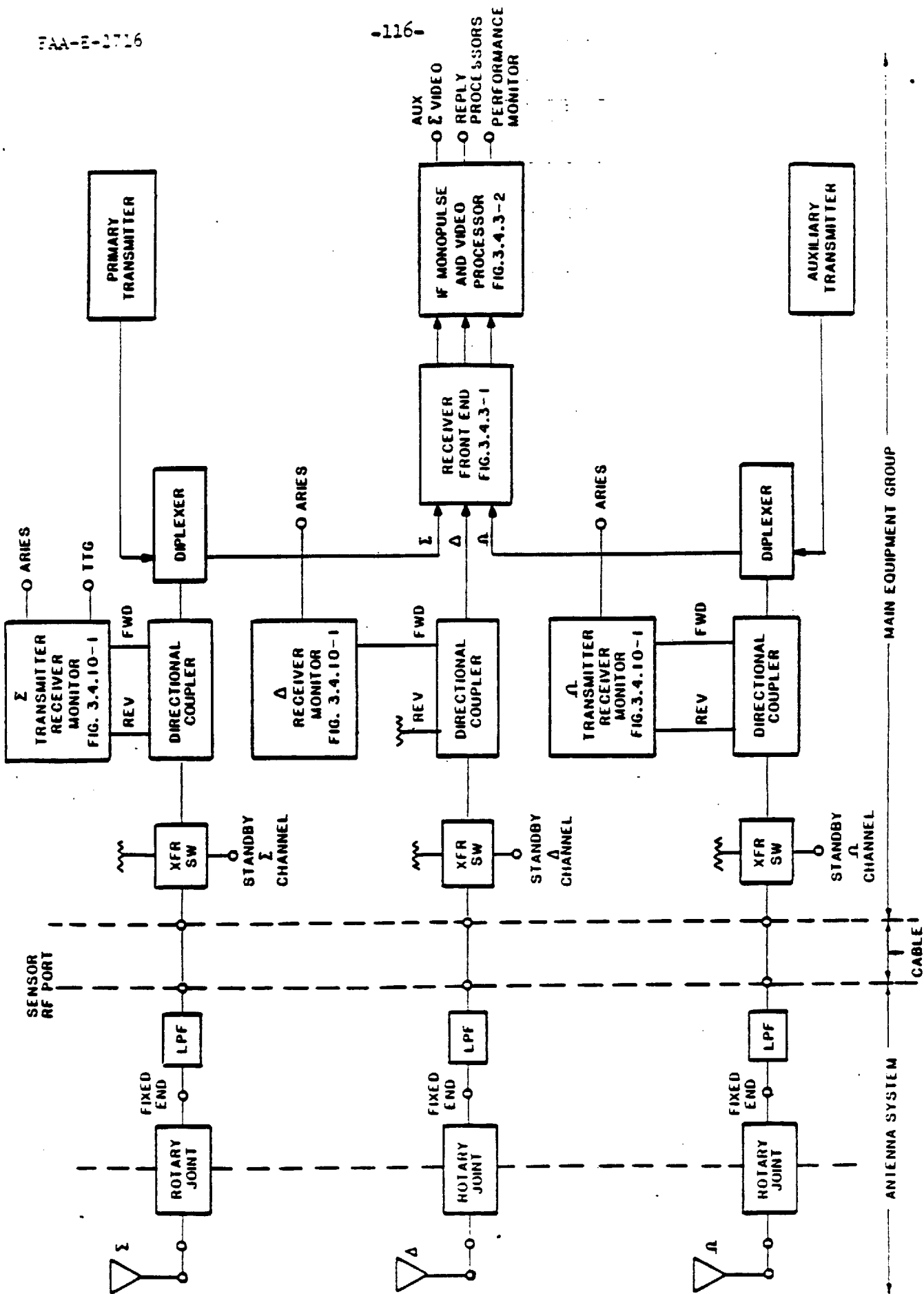


FIG. 3.4.2-3. RF SYSTEM BLOCK DIAGRAM

specifications regarding the transmitters and the receivers. Between the sensor RF port and the main equipment group there is a transmission line whose length may be as great as 100 ft. The primary and auxiliary transmitters shall be all solid state. Tube type designs are not permitted.

3.4.2.3.1 Primary transmitter.- The primary transmitter shall operate in three modes: a high-power Mode S mode, a low-power Mode S mode, and an ATCRBS mode. Both Mode S modes shall be capable of handling all of the Mode S interrogation types defined in the Mode S National Standard including extended length message (ELM) transmissions. ATCRBS interrogations, ATCRB/Mode S All-Call interrogations, ATCRBS-only All Call interrogations, and Mode S Only All-Call interrogations, are transmitted at the ATCRBS power level. All other interrogations are transmitted at either the Mode S-High or Mode S-low power level, the selection being determined by the high/low power indicator in the transmission control block. A common transmitter design shall be used for Mode S Type I, II, and III sensors.

3.4.2.3.1.1 Power output and duty factor.- In the high-power Mode S mode the primary transmitter shall be capable of producing a peak power of at least 800 watts and a long-term average power of 16.2 watts, both referred to the sensor RF port. In addition the Mode S high-power level shall be manually adjustable downward in 2 dB steps to a level 10 dB below the maximum. The averaging time requirements for the high-power mode are as follows. In the high-power mode the transmitter shall be capable of initiating:

- (a) at least 1 long (112-bit) Mode S interrogation in any 50- μ sec interval,
- (b) up to 24 long Mode S interrogations in any 4-msec interval,
- (c) up to 60 long Mode S interrogations in any 100-msec interval.

In the low-power Mode S mode the primary transmitter shall produce a peak power adjustable between -5 dB and -9 dB, in 1 dB increments relative to the high Mode S power level, and shall be capable of a long-term average power of at least 11.5 watts referred to the sensor RF port. The averaging time requirements for the low-power mode are as follows. In the low-power mode the transmitter shall be capable of initiating:

- (a) at least 1 long (112-bit) Mode S interrogation in any 50- μ sec interval,
- (b) up to 32 long Mode S interrogations in any 2-msec interval,
- (c) up to 96 long Mode S interrogations in any 40-msec interval,
- (d) up to 3440 long Mode S interrogations in any 2-sec interval,
- (e) up to 4720 long Mode S interrogations in any 4-sec interval.

In the ATCRBS mode, the primary transmitter shall be capable of producing a peak power which can be manually set between the Mode S high-power level and a level 10 dB lower in 2 dB steps. The nominal setting is 4 dB below the Mode S high-power level for a Mode S Type I sensor, and 0 dB for Type II and Type III sensors.

In addition to the Mode S interrogation rates specified above, the transmitter shall be capable of transmitting ATCRBS/Mode S (or pairs of ATCRBS-Only All-Call and Mode S-Only All-Call) interrogations at a uniform rate of up to 150 per second at the ATCRBS power level.

The transmitter shall be capable of transmitting an interlaced combination of any of the externally generated inputs, including Mode 4, and an internally generated ATCRBS interrogation at a uniform rate of up to 450 interrogations per second in lieu of the standard Mode S/ATCRBS transmissions (see Appendix V, Mode S Sensor Requirements for Joint Use Sites).

3.4.2.3.1.2 Carrier frequency.- The output frequency of the transmitter shall be 1030 ± 0.01 MHz.

3.4.2.3.1.3 Waveform fidelity.- The transmitter output waveform as measured at the sensor RF port (fig. 3.4.2-3) shall satisfy the waveform requirements given in the Mode S National Standard. The total amplitude droop over a 32-segment ELM transmission shall not exceed 2 dB.

3.4.2.3.1.4 Spurious emissions.- The radiated spectrum for transmissions of any message type shall comply with the Mode S National Standard.

The transmitter output shall be filtered to produce power levels in a band at 1090 ± 10 MHz that are less than +10 dBm as measured at the sensor RF port. For time intervals during which the transmitter is actively producing an interrogation, the spurious signal and noise side-band power shall be limited to a level at least 80 dB below peak carrier power, as measured at the sensor RF port. Harmonic radiated power shall be at least 50 dB below the fundamental output.

For time intervals during which the transmitter is in the OFF state and not actively producing transmissions, the noise power spectral density delivered to the output terminals shall not exceed -170 dBm/Hz in the band 1085 MHz to 1095 MHz and -104 dBm/Hz elsewhere. The CW power output at any frequency shall not exceed -60 dBw when the transmitter is in the OFF state.

3.4.2.3.2 Auxiliary transmitter.- The auxiliary transmitter shall generate the P_5 pulse (PAM - 0.8 μ s long) for Mode S SLS as well as the P_2 or P_1 and P_2 pulses for ATCRBS SLS or improved ISLS.

-119-

3.4.2.3.2.1 Power output and duty factor.- The auxiliary transmitter shall be automatically controlled to follow the primary transmitter in the sense that for a particular interrogation, the peak auxiliary power equals the peak primary power plus DELS or DELA where DELS and DELA are parameters, manually controllable over the range 0 to 9 dB, in 1 dB steps. The peak auxiliary power for the P5 pulse shall equal the peak primary power plus DELS. The peak auxiliary power for P2 or P1 and P2 shall equal the peak primary power plus DELA. The auxiliary transmitter shall follow this performance within ± 1 dB. The duty factor of the auxiliary transmitter shall be consistent with the interrogation rates of the primary transmitter specified above. The auxiliary transmitter shall be capable of producing at least 3200 watts peak power at the sensor omni RF port. The 9 dB separation is necessary only at primary transmitter power levels of 400 watts or less. The auxiliary transmitter peak power is not required to exceed 3200 watts.

3.4.2.3.2.2 Carrier frequency.- The output frequency of the auxiliary transmitter shall be 1030 ± 0.1 MHz.

3.4.2.3.2.3 Waveform fidelity.- The auxiliary transmitter output pulse waveform as measured at the sensor RF port (fig. 3.4.2-3) shall satisfy the waveform fidelity requirements given in the Mode S National Standard.

3.4.2.3.2.4 Spurious emissions.- The auxiliary transmitter requirements on spurious emissions are as specified for the primary transmitter (3.4.2.3.1.4), except that the radiated spectrum shall be bounded by that of a 0.80 μ s trapezoidal pulse with a rise and fall time of 50 ns.

3.4.2.4 Transmit/receive isolation.- The output of the transmitters shall be fed through suitable transmission lines to transmit/receiver diplexers. The isolation between transmit and receive ports shall provide sufficient isolation to prevent damage to the receiver circuits when the sensor output is connected to shorts or opens at any phase angle over the entire range of transmitter power levels.

3.4.2.5 Transmitter protection.- The transmitters shall contain self-protect circuitry to prevent damage in case demands exceeding their rated capacity are imposed by modulation control or output loading. Suitable protection devices shall be provided to protect the transmitters from loads up to and including shorts or opens at any phase angle.

3.4.2.6 Sum, difference and omni-direction couplers.- Directional couplers shall be provided in the output paths between the diplexers and the sensor RF port to support performance monitoring functions (3.4.10) and for the manual injection and extraction of RF signals. The same directional coupler may be used for both functions. If the same coupler is used, it shall be possible to insert or extract the RF signals without the need to disconnect or disrupt the performance monitoring functions. Each coupler shall have one incident port and one extraction port. Each coupler shall meet the following requirements:

Frequency Range	1010 to 1110 MHz
Power Handling	Capable of handling Mode S peak and overall power requirements

FAA-E-1716 & AMEND.-2
SCN-7 (Change 13)

Insertion Loss	0.25 dB maximum
VSWR	1.25:1 maximum
Coupling Factor	Incident Port 20 dB \pm 0.5 dB Reflected Port 15 dB \pm 0.5 dB
Directivity	Incident 20 dB Reflected 35 dB

Each output port shall be calibrated within \pm 0.1 dB, and the measured value recorded on the maintenance panel. The RF injection/extraction coupler shall be calibrated, at the time of installation, within \pm 0.2 dB referenced to the Sensor RF Port, and the measured value recorded on the equipment maintenance panel. The Sensor RF Port is defined as the rotary joint end of the cable connected to the sensor front end.

This space intentionally unused

3.4.3 Multichannel receiver.- The multichannel receiver processes RF signals which are input to the system from the Mode S sensor antenna and outputs video and quantized (two-level) video signals to both the Mode S and the ATCRBS reply processors (3.4.4 and 3.4.5). It also provides auxiliary logarithmic video and quantized video outputs for backup and military beacon systems. The sensor antenna consists of three channels, each of which has a different azimuthal coverage pattern and gain, and is named as follows (the symbols Σ , Δ , Ω , are used to denote the complex amplitudes of signals):

- (a) Sum symmetrical pattern channel (Σ).
- (b) Difference antisymmetrical pattern channel (Δ).
- (c) Omnidirectional pattern channel (Ω).

The block diagram of fig. 3.4.2-3 shows the interconnection of the receiver to the rest of the RF system. The multichannel receiver consists of two major subfunctions, the front-end and IF/video processor, with the following capabilities:

- (a) Front end: (Fig. 3.4.3-1)

Conversion of Σ , Δ to A, B

Channel bandlimiting at RF

RF preamplification

Frequency conversion to IF

IF signal amplification

Local oscillator generation and distribution system for frequency conversion

- (b) IF/video processor: (Figs. 3.4.3-2 and 3)

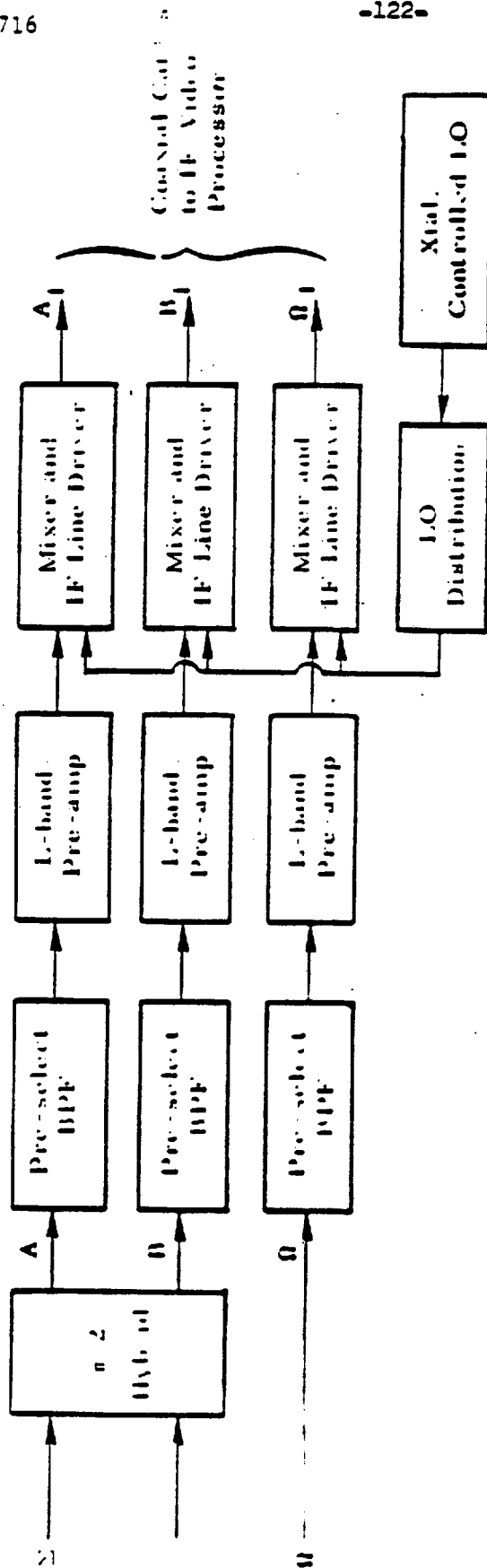
IF bandpass filtering

Signal distribution for monopulse processing

A_1 , B_1 and Σ signal processing for monopulse off-boresight estimation

Logarithmic processing of the magnitude of Σ , Δ , and Ω signals

Video signal processing to develop QED, QEA, QEPS, QENS, QSLSD, and QLSA.



BPF - Bandpass Filter
LO - Local Oscillator

FIGURE 3.4.3-1
RECEIVER FRONT-END BLOCK DIAGRAM

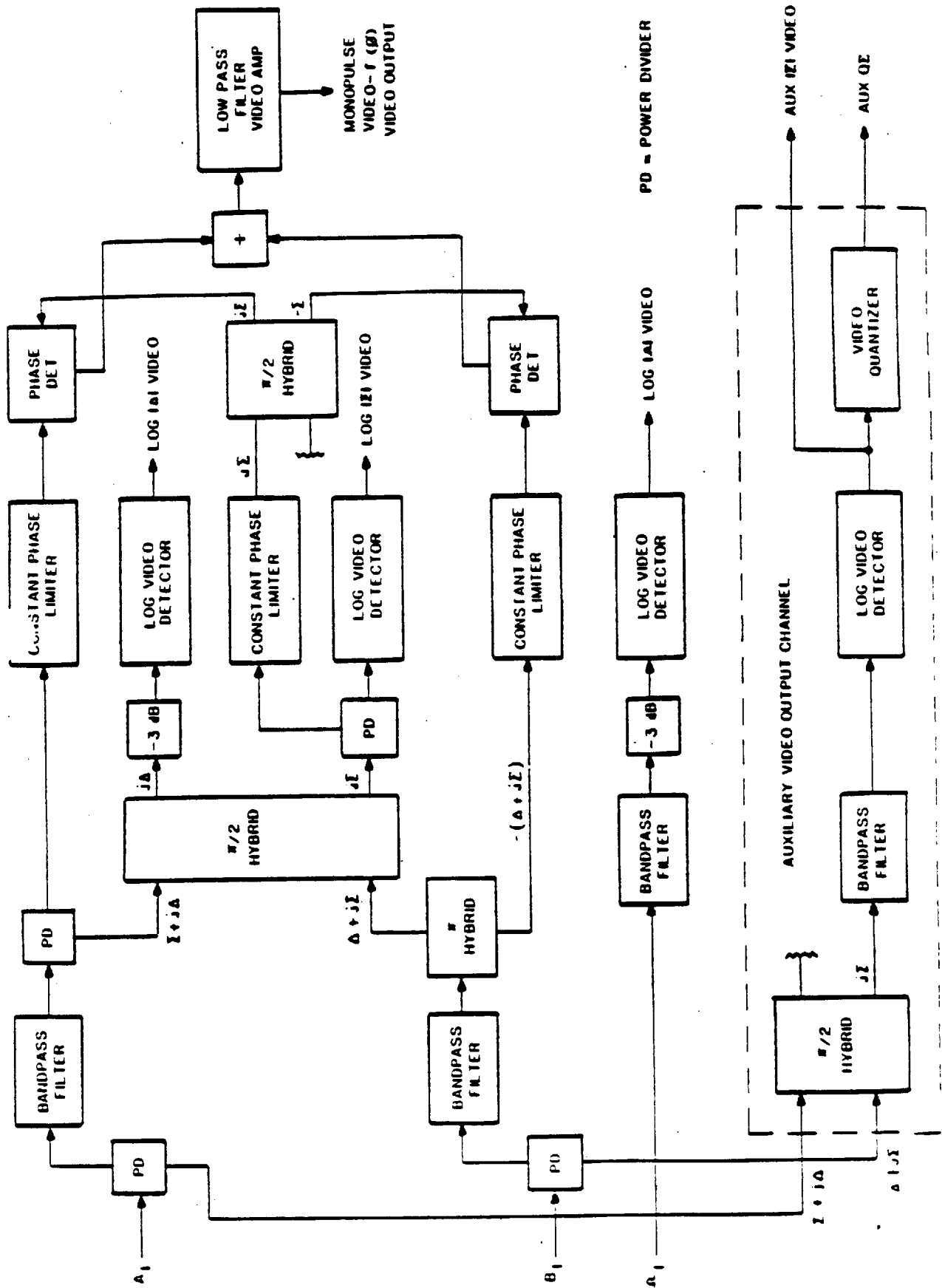


Fig 3 4.3-2 IF Monopulse Processor and Auxiliary Video Output Channel Block Diagram

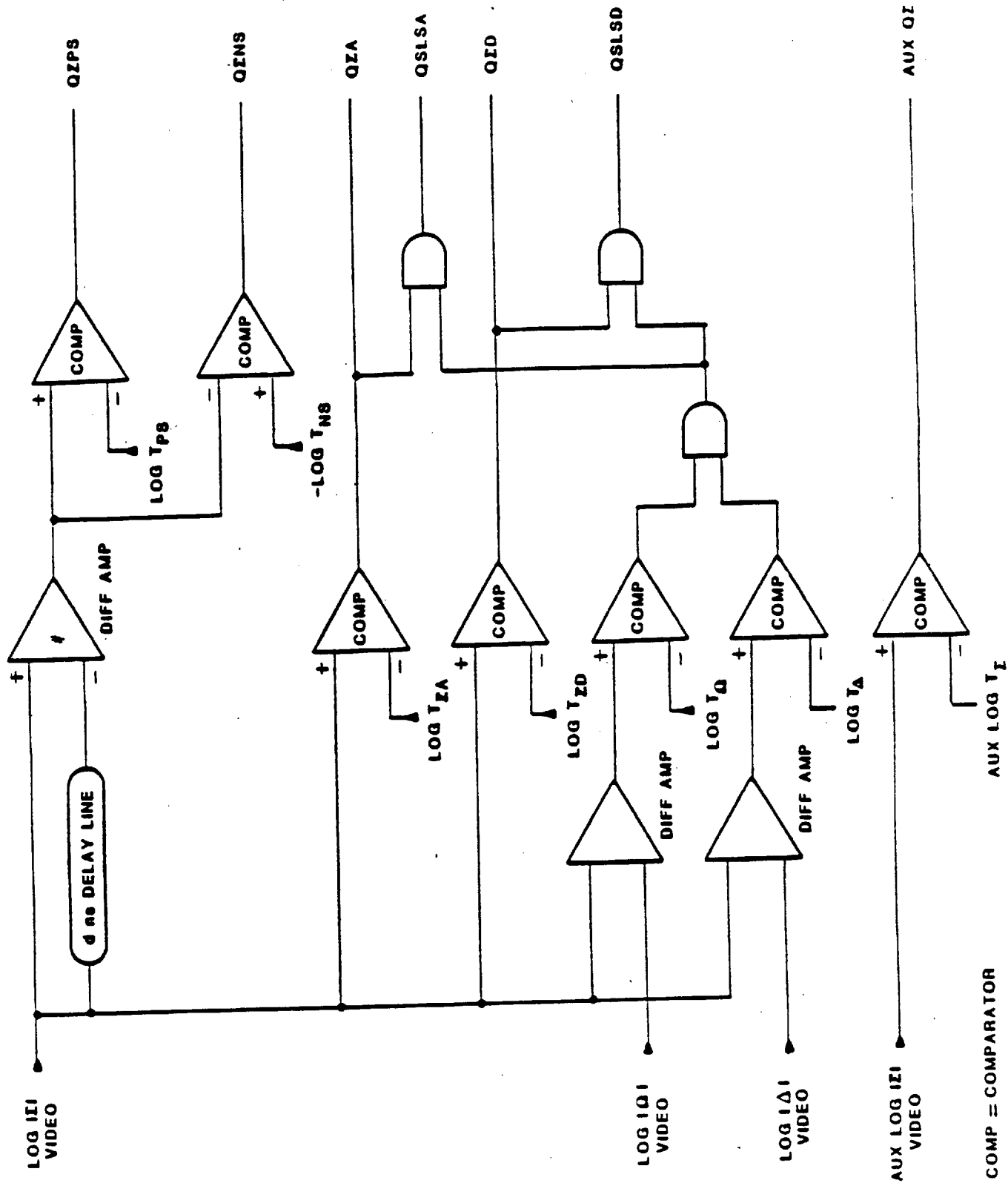


Fig. 3.4.3-3. Video Quantizer

(c) Auxiliary IF processor: (Figs. 3.4.3-2 and 3)

IF bandpass filtering

Logarithmic processing of the magnitude the of Σ signalVideo signal processing to develop Aux Q Σ

The phase and amplitude response requirements listed in this and the following paragraphs are minimum values only. The system may require increased accuracy to meet the monopulse azimuth estimation requirements.

3.4.3.1 General description. - The monopulse receiver shall operate on the beacon signals (Mode S and ATCRBS) received on the three antenna channels. The Σ and Δ signals shall first be combined in the receiver front-end to form the signals:

$$A = (\Sigma + j\Delta)/\sqrt{2}$$

$$B = j(\Sigma - j\Delta)/\sqrt{2}$$

The A, B, and Ω signals shall then be translated in frequency to an intermediate frequency (IF) where they shall be filtered and amplified. The IF signals A_1 and B_1 output by the receiver front-end, i. e.,

$$A_1 = (\Sigma + j\Delta)/\sqrt{2}, \text{ and}$$

$$B_1 = j(\Sigma - j\Delta)/\sqrt{2},$$

shall then be input to the monopulse IF/video processor where they shall be recombined to give:

$$(B_1 + jA_1)/\sqrt{2} = j\Sigma$$

This signal shall be used together with the A_1 and B_1 signals to drive two matched phase detectors whose outputs are summed to produce the monopulse video signal, ϕ , defined as follows (Arg denotes the argument of a complex amplitude expressed in polar form):

$$\phi = [\text{Arg } A_1 - \text{Arg } j\Sigma] + [\text{Arg } (-\Sigma) - \text{Arg } B_1]$$

Processing of the video function $f(\phi)$, that relates the monopulse channel output to the off-boresight angle, to provide north-related, calibrated and digitized azimuth data is specified in 3.4.11.

The recovered Σ , Δ , and Ω IF signals shall be input to separate but matched logarithmic amplifier/detectors to produce video signals denoted as $\text{Log } |\Sigma|$, $\text{Log } |\Delta|$, and $\text{Log } |\Omega|$. The $\text{Log } |\Sigma|$ signal shall be processed by a video threshold comparator to produce the two-level quantized sum video signals denoted Q Σ D and Q Σ A. In addition, the slope of the $\text{Log } |\Sigma|$ signal shall be processed by video

threshold comparators to produce the quantized video signals indicating positive and negative slopes exceeding a preset threshold (denoted QEPS and QENS). $\text{Log } |\Sigma|$, $\text{Log } |\Delta|$, and $\text{Log } |\Omega|$ shall also be processed by two video comparator circuits to produce quantized video signals (QSLSD and QSLSA) which indicate when the $|\Sigma|/|\Omega|$ ratio is above a fixed threshold, T_Ω , and $|\Sigma|/|\Delta|$ is above a fixed threshold, T_Δ . Note that a suffix "D" indicates a Mode S signal and a suffix "A" indicates an ATCRBS signal.

The IF signals A_1 and B_1 shall also be input to the auxiliary video output channel where they shall be recombined to give:

$$(B_1 + jA_1) / \sqrt{2} = j\Sigma$$

This signal shall be filtered and fed to a logarithmic amplifier/detector to produce an auxiliary video signal denoted as Aux $\text{Log}|\Sigma|$ video. The Aux $\text{Log}|\Sigma|$ video signal shall be further processed by a video threshold comparator to produce the two-level quantized auxiliary sum video signal denoted as Aux Q Σ .

3.4.3.2 Overall receiver requirements.- This section contains the overall receiver requirements, which are critical to the Mode S and ATCRBS signal processing subsystems. These requirements are dictated specifically by the functional requirements of pulse detection, two pulse resolution, side and back lobe discrimination, and monopulse (off-boresight angle-of-arrival) estimation.

Subsequent sections cover the requirements of the front end and IF/video processor separately. The individual subfunction specifications are consistent with the overall receiver requirements for a system using a half angle phase monopulse estimator but, by themselves, cannot ensure that the overall requirements can be met because of the careful interconnection of the components and subfunction required in this application. Should an apparent contradiction arise between overall requirements and a subfunction specification, the overall requirements shall take precedence. A receiver design which consists of subfunctions having specifications differing from those described in this document (due to a different allocation of tolerances), but which nevertheless meets the overall receiver requirements shall be submitted to the government for approval. Where the reallocation changes the subfunction specifications of paragraphs 3.4.3.3 and 3.4.3.4, all subfunctions shall be tested and accepted based on compliance with the revised and approved specifications.

The receiver section describes a half angle phase monopulse azimuth estimator. Alternate amplitude monopulse azimuth estimators may be proposed with appropriate modifications to the phase and amplitude specifications within the receiver. The amplitude monopulse azimuth estimator shall meet all system azimuth accuracy requirements.

3.4.3.2.1 Definitions. - The following terms apply to the receiver and Mode S and ATCRBS processing subsystems.

Receiver Normal Operating Range - The receiver requirements shall apply for signals at the sensor RF port ranging from -79 dBm to -20 dBm in dynamic range and from 1087.0 MHz to 1093.0 MHz in frequency.

MTL - Minimum Threshold Level, is defined as the minimum signal level, referred to the sensor RF port, which will provide a reply detection probability of 0.9. Specifically, the receiver threshold is established so that ATCRBS and Mode S replies received at a level of -79 dBm shall have a 0.9 detection probability when the receiver is simultaneously exposed to no interfering replies.

Standard Test Pulse - An RF pulse with a trapezoidal envelope, 450 ns wide at a level 6 dB below peak amplitude, and with rise and fall times of 100 ns from 1 dB below peak amplitude to 40 dB below peak.

3.4.3.2.2 Overall noise figure. - The RF losses and gain schedule of the front-end and IF/video processor, together with the RF coaxial cable losses, shall result in at most a 10.5 dB system noise figure, referred to the sensor RF port (fig. 3.4.2-3).

3.4.3.2.2.1 Tangential sensitivity. - The RMS system noise level at the sensor RF port, as measured by the following method, shall be -95dBm, maximum: Using the RF port as the injection point and the aux video output port as the monitor point, inject 1090MHz CW until the monitored quiescent noise level is increased by 3dB (or 3C mv, where C = log slope in mv/db). The injected signal level referred to the sensor port shall then be less than -92dBm.

3.4.3.2.3 Overall monopulse accuracy. - A calibration curve shall be derived for the monopulse channel to define the relationship between the ratio Δ/Σ at the sensor RF port and the digitized samples of monopulse video. The calibration shall be obtained with a standard test pulse at a frequency of 1090 MHz and a level of -50 dBm at the Σ channel RF port. The Δ/Σ ratio shall be precisely varied between the limits -2 and +2 (i.e., +6 dB to -30 dB in and out of phase). The calibration data are to be smoothed by the method selected for initial calibration of a sensor (see 3.4.11). This calibration curve shall be employed to produce estimates of Δ/Σ for pulse inputs at frequencies between 1087 MHz and 1093 MHz and Σ levels from -79 dBm to -20 dBm except the ($\Sigma + j\Delta$) and ($\Delta + j\Sigma$) levels are not expected to exceed the level corresponding to $\Sigma = -20$ dBm at boresight.

When a standard test pulse is introduced at the sensor Σ and Δ RF ports, the monopulse video output shall have a stable region of 0.2 μ s whose location with respect to the pulse leading edge remains invariant over the dynamic range and frequency variations. Samples taken over the levels and frequencies stated above, and at any single point during the 0.2 μ s interval shall yield an estimate of Δ/Σ with a peak-to-peak variation not exceeding 0.10 ($1 + |\Delta/\Sigma|^2$), 0.025 ($1 + |\Delta/\Sigma|^2$) rms, for Δ/Σ within the calibration limits. In addition, the maximum variation from the calibration point (1090 MHz and -50 dBm) measurement shall not exceed 0.062 ($1 + |\Delta/\Sigma|^2$).

Pulse-to-pulse averaging will be required for signals in the range -50 to -80 dBm for samples at one point within the 0.2 μ s window.

At 1090 MHz, with the Δ RF port terminated and a standard test pulse at the Σ RF port at a level of -79 dBm, the output shall at any time within the same 0.2 μ s window indicate a Δ/Σ ratio less than 0.15 rms.

3.4.3.2.4 Overall video performance. - The following overall performance requirements apply from the (Σ , Δ , Ω) RF inputs referred to the sensor RF port to the outputs of the four log detectors in the IF/video processor labeled Log $|\Sigma|$, Log $|\Delta|$, Log $|\Omega|$, and Aux Log $|\Sigma|$, in fig. 3.4.3-2. Input signals (CW and pulse) shall be varied over the receiver normal operating range (3.4.3.2.1).

- (a) Differential amplitude - The peak pulse amplitudes of Log $|\Omega|$ relative to Log $|\Sigma|$, and the peak pulse amplitudes of Log $|\Delta|$, relative to Log $|\Sigma|$, shall be within ± 1.0 dB for standard RF input pulses of equal amplitude and varying over the full dynamic and frequency range. All time intervals shall be with respect to the 3 dB below peak amplitude point.
- (b) Differential delay - The pulse delay of the output Log $|\Omega|$ relative to Log $|\Sigma|$, and the delay of Log $|\Delta|$, relative to Log $|\Sigma|$, shall be no more than ± 25 ns for standard RF input pulses of equal amplitude and varying over the full dynamic and frequency range.
- (c) Log video fall time - The output log video fall time shall exceed a slope of -140 dB/ μ s from the -3 dB point to the -40 dB point, and shall be monotonic from -3 to -30 dB for standard RF input pulses in the range -20 to -55 dBm over the full frequency range of 1087 MHz to 1093 MHz for Log $|\Sigma|$, Log $|\Delta|$, and Log $|\Omega|$. For Aux Log $|\Sigma|$ log video output, the fall time shall exceed a slope of -140 dB/ μ s from the -3 dB point to the -20 dB point and shall be monotonic from -3 to -20 dB for standard RF input pulses in the range -20 to -55 dBm over the full frequency range of 1087 MHz to 1093 MHz. There shall be no time sidelobes higher than -30 dB with respect to peak for Log $|\Sigma|$, Log $|\Delta|$, and Log $|\Omega|$ and no time sidelobes higher than -20 dB with respect to peak for Aux Log $|\Sigma|$.
- (d) Pulse stretching - The output log video pulsewidth as measured at the 6 dB level shall be equal to the RF input pulsewidth plus 50 nanosec, minus 0 nanosec.

3.4.3.2.5 Overall Receiver Interference Rejection. - The receiver shall be capable of operating in the presence of CW and pulsed CW interference applied over the range of 1080 MHz to 1100 MHz as follows.

3.4.3.2.5.1 CW Interference. - The receiver shall meet all Mode S and ATCRBS reply detection requirements in the presence of CW interference for replies whose peak amplitudes exceed the peak amplitude of the interference by J_C dB, where $J_C = 6[3 - 12, 1]$, for CW levels between -95 dBm and -20 dBm whose total power of CW + reply peaks are within the dynamic range of the receiver as defined in 3.4.3.3.2. The receiver shall adjust T_{SD} and T_{SA} appropriately within 2-milliseconds of the detection of the CW interference. T_{SD} and T_{SA} shall be continuously adjusted to a) reject the CW interference, and b) detect higher amplitude replies.

The azimuth(s) of all detected CW interferers shall be reported to the performance monitor (3.4.10.2.2).

3.4.3.2.5.2 Pulsed Interference.- RF input pulse train #2 as described in 3.4.3.2.5.2 (b) shall be impressed at the receiver input in such a manner that the leading edge of the first pulse of the train occurs 0.7 μ s after the leading edge of any pulse of RF input pulse train #1 described in 3.4.3.2.5.2 (a) and impressed at the receiver input. The resultant signals produced across a 75 ohm terminating resistor at the auxiliary video channel output shall be as described in 3.4.3.2.5.2 (c).

(a) Input Pulse Train #1.

- | | |
|--------------------------|---|
| (1) Number of pulses | 15 |
| (2) Spacing of pulses | First and last pulse spaced $20.3 \pm 0.1 \mu$ s leading edge to leading edge; other pulses equally spaced in increments of $1.45 \pm 0.05 \mu$ s from leading edge of first pulse. |
| (3) Amplitude | -40 dBm referred to the sensor RF port. |
| (4) Duration of pulses | 0.55μ s ± 0 , -0.05μ s |
| (5) Rise time of pulses | 0.1 μ s maximum |
| (6) Decay time of pulses | 0.2 μ s maximum |
| (7) Droop of pulse train | Not greater than 2% |
| (8) Frequency | 1090.00 MHz |

(b) Input Pulse Train #2.

- | | |
|--------------------------|---|
| (1) Number of pulses | 15 |
| (2) Spacing of pulses | First and last pulse spaced $20.3 \pm 0.1 \mu$ s leading edge to leading edge; other pulses equally spaced in increments of $1.45 \pm 0.05 \mu$ s from leading edge of first pulse. |
| (3) Amplitude | -60 dBm referred to the sensor RF port. |
| (4) Duration of pulses | 0.55μ s ± 0 , -0.05μ s |
| (5) Rise time of pulses | 0.1 μ s maximum |
| (6) Decay time of pulses | 0.2 μ s maximum |
| (7) Droop of pulse train | Not greater than 2% |
| (8) Frequency | 1090.00 MHz |

(c) Output Pulse Train Produced by Input Pulse Train #2.

- (1) Number of pulses 15
- (2) Spacing of pulses First and last pulse spaced $20.3 \pm 0.1 \mu\text{s}$ leading edge to leading edge; other pulses equally spaced in increments of $1.45 \pm 0.05 \mu\text{s}$ from leading edge of first pulse.
- (3) Amplitude Quantized: full output
Nonquantized: 0.8 volts
- (4) Duration of pulses $0.55 \pm 0.05 \mu\text{s}$
- (5) Droop of pulse train Not greater than 2%

3.4.3.3 Front end.

3.4.3.3.1 General.- The front end shall accept RF sum and difference inputs from the monopulse antenna channels via two amplitude and phase matched coaxial cables. It shall also receive RF inputs from the omni channel.

The coaxial cables to transmit the A_1 , B_1 and Ω_1 channel IF signals from the monopulse RF processor to the IF/video processor shall be included as part of the multichannel receiver.

3.4.3.3.2 Dynamic range and gain.- The expected dynamic range of RF input signals will be from the noise level to -20 dBm referred to the sensor RF port. The three channels shall be linear over this dynamic range with less than 1 dB compression at the output for -20 dBm input.

3.4.3.3.3 Frequency response.- The frequency response of the front end shall have the following characteristics as measured from the RF inputs (A, B, Ω) to the corresponding IF outputs (A_1 , B_1 , Ω_1).

3.4.3.3.3.1 Amplitude response.

- (a) Center frequency: 1090 MHz nominal
- (b) Bandwidth: Flat to within ± 0.25 dB from 1087 MHz to 1093 MHz.
Flat to within 1 dB from 1083 MHz to 1097 MHz.
Flat to within 3 dB over the band ± 12 MHz, centered at 1090 MHz.

The response shall drop monotonically outside of the 3 dB limits to -60 dB, and shall be at least -60 dB referred to the response at 1090 MHz over the band 225 MHz to 1035 MHz, and over the band 1150 MHz to 3000 MHz.

(c) Differential channel amplitude response:

B relative to A: ± 0.5 dB over the band 1083 MHz to 1097 MHz.

B relative to A: ± 0.5 dB over the band 1083 MHz to 1097 MHz.

3.4.3.3.2 Phase response.

(a) Linearity:

The channel transfer phase response shall be linear to within $\pm 10^\circ$ over the band 1083 MHz to 1097 MHz.

(b) Differential Phase:

B relative to A shall be:

within $\pm 1.5^\circ$ over the band 1087 MHz to 1093 MHz.

within $\pm 3.0^\circ$ over the band 1083 MHz to 1097 MHz.

3.4.3.3.4 High-level signal protection.- The front end shall not suffer any degradation in performance (overall gain or noise figure) 2 μ s after being subjected to continuous high-level input signals of +10 dBm or transient inputs of +30 dBm (for 1 μ s and 0.001 duty cycle).

3.4.3.3.5 Test points.- Test points for monitoring the performance of the front-end shall be provided in accordance with the requirements of the performance monitoring function (3.4.10).

3.4.3.3.6 Image rejection.- The image frequency band shall be rejected by at least 90 dB, referred to the response at 1090 MHz.

3.4.3.3.7 Local oscillator.- The LO shall be 1030 MHz \pm 0.01%.

3.4.3.4 IF/Video processor.

3.4.3.4.1 General.- The IF/video processor shall accept IF inputs from the front-end via phase and amplitude matched coaxial cables, without degrading either overall noise performance or accuracy of the monopulse channel.

3.4.3.4.2 IF bandpass filters.- The IF filters are critical to the pulse fidelity and monopulse accuracy obtained at the receiver output. The detailed requirements of the IF filters are given below:

(a) Frequency Response:

IF Frequency	60 MHz
Bandwidth	8 +1, -0 MHz at -3 dB points < 30 MHz at -40 dB points
Phase Response	Linear within $\pm 10^\circ$ over 14 MHz range centered on IF
Differential Amplitude	All three filters within ± 0.5 dB at IF.
Differential Phase	Channel A, B, filters to within $\pm 3^\circ$ over the 14 MHz range centered at IF.

(b) Pulse Response (To a standard test pulse as in 3.4.3.2.1):

Rise time	<160 ns; from 40 dB below peak to 3 dB below peak.
Fall time	<160 ns; from 3 dB below peak to 40 dB

3.4.3.4.3 Limiter/phase detector (monopulse) channels.-

- (a) Accuracy - For coherent CW inputs, the limiter/phase detector subunit output shall be calibrated to indicate the relative phase of inputs A_1 and B_1 to within $\pm 3^\circ$ for all frequencies within ± 3 MHz of the IF nominal center frequency, and for phase differences between A_1 and B_1 in the range $+40^\circ$ to -220° and for signal amplitudes at A_1 and B_1 which are consistent with RF signals input to the sensor RF port in the range -20 dBm to -79 dBm.

One single calibration curve shall be used to translate the phase detector video output into relative phase between A_1 and B_1 to within $\pm 3^\circ$ over the full dynamic and frequency range.

- (b) Pulse response - For standard test signals at A_1 and B_1 the phase detector output shall reach the nominal steady state value within 200 ns of the input pulse leading edge and maintain that value to within $\pm 1.5^\circ$ for 200 ns. This requirement shall be satisfied for all pulse amplitudes and frequencies within the receiver normal operating range.

3.4.3.4.4 Logarithmic amplifier/detectors.- The logarithmic amplifier/detectors shall have the following characteristics:

Input dynamic range	74 dB, corresponding to the range -20 dBm to -94 dBm referred to the sensor RF port.
Linearity	Linear to within ± 0.5 dB over the range -20 dBm to -79 dBm referred to the sensor RF port.
Output level stability	The transfer characteristic (volts out vs RF input level in the range -20 dBm to -79 dBm referred to the sensor RF port) shall be stable to within the equivalent of ± 1 dB, for periods in excess of 1000 hours.
Rise time of video output	The output shall rise from -40 dB referred to peak to -3.0 dB referred to peak in ≤ 100 ns for an IF pulse input with a rise time of less than 20 ns.
Fall time of video output	The output shall fall from -3.0 dB referred to peak to -40 dB referred to peak in ≤ 100 ns for an IF pulse input with a fall time of less than 20 ns.

3.4.3.4.5 Video quantizer.- The video quantizer shall operate on $\text{Log } |\Sigma|$, $\text{Log } |\Delta|$, and $\text{Log } |\Omega|$ video signals to produce six different output signals quantized in amplitude to two levels (see fig. 3.4.3-3). The transition time between levels in all quantized video signals shall be no more than 20 ns.

3.4.3.4.5.1 Quantized sum video.- The quantized sum video signals (denoted Q Σ D and Q Σ A) shall be derived from the $\text{Log } |\Sigma|$ video signal according to the following rules. Denoting the IF signal envelope on the Σ channel at time t as $\Sigma(t)$, the Q Σ D signal shall be in the '1' state whenever $\Sigma(t)$ exceeds a threshold, and shall be in the '0' state otherwise. That is:

$$Q\Sigma D = \begin{cases} 1 & \text{whenever } |\Sigma(t)| > T_{\Sigma D} \\ 0 & \text{otherwise} \end{cases}$$

Note: Suffix "D" designates Mode S signal;
suffix "A" designates ATCRBS signal.

The Q Σ A signal is defined as follows:

$$Q\Sigma A = \begin{cases} 1 & \text{whenever } |\Sigma(t)| > T_{\Sigma A} \\ 0 & \text{otherwise} \end{cases}$$

3.4.3.4.5.1.1 Detection threshold.- The detection threshold $T_{\Sigma D}$, shall be the greater of three terms:

$$T_{ED} = \max \{T_{FD}, T_{ADAPD}, T_{STCD}\}$$

where T_{FD} is a fixed threshold, T_{ADAPD} is a signal dependent, adaptive term, and T_{STCD} is a time-varying term.

The detection threshold T_{EA} shall be the greater of three terms

$$T_{EA} = \max \{T_{FA}, T_{ADAPA}, T_{STCA}\}$$

where T_{FA} is a fixed threshold, T_{ADAPA} is a signal dependent, adaptive term, and T_{STCA} is a time-varying term.

The nominal setting of T_{FD} shall be such that with $T_{ED} = T_{FD}$ a long Mode S reply input at the sensor RF port at a level of -79 dBm would be detected with a probability of 0.9 in the presence of no fruit or synchronous garble.

There shall be provision for manually adjusting the threshold T_{FD} over a range corresponding to RF signal inputs from -90 dBm to -65 dBm in steps no greater than 1/2 dB.

The nominal setting of T_{FA} shall be such that with $T_{EA} = T_{FA}$ an ATCRBS reply bracket input at the sensor RF port at a level of -79 dBm would be detected with a reply probability of 0.9 in the presence of no fruit or synchronous garble. There shall be provision for manually adjusting the threshold T_{FA} over a range corresponding to RF signal inputs from -90 dBm to -65 dBm in steps no greater than 1/2 dB.

3.4.3.4.5.1.2 Adaptive threshold.- Adaptive thresholds, T_{ADAPD} and T_{ADAPA} , shall be provided to reduce the likelihood of detecting low-level multipath as reply pulses and to reject CW interference. Multipath rejection shall be accomplished by referring the detection threshold to the amplitude of the last detected pulse. Whenever a pulse whose width is greater than 300 ns and whose $Q \geq D$ ($Q \geq A$) is set to a '1', is detected, $\log T_{ADAPD}$ ($\log T_{ADAPA}$) shall be set to a value K dB below the amplitude of that pulse or set to zero, whichever is greater. After τ μ s T_{ADAP} is reset to 0. $\log T_{ADAPD}$ ($\log T_{ADAPA}$) shall not be changed if the pulse width is less than 200 ns.

$$T_{ADAPD} = \max ((\log |I_1| - K_D), 0) \text{ for } t < \tau_D$$

$$T_{ADAPA} = \max ((\log |I_1| - K_A), 0) \text{ for } t < \tau_A$$

where t is the time elapsed since the last detected pulse, and $\log |I_1|$ is the amplitude of that pulse. K_D shall have a nominal value of 20 dB. There shall be provision for manually adjusting K_D in steps no greater than 1 dB over the range 15 dB to 30 dB. τ_D shall have a nominal value 12 μ s. There shall be provision for manually adjusting τ_D over the range 12 μ s to 125 μ s. T_{ADAPA} shall be reset at the end of each Mode S reply.

K_A shall have a nominal value of 20 dB. There shall be provision for manually adjusting K_A in steps no greater than 1 dB over the range 15 dB to 30 dB. τ_A shall have a nominal value 10 μ s. There shall be provision for manually adjusting τ_A over the range 2 μ s to 26 μ s.

There shall be provision for disabling either or both of the adaptive thresholds, i.e., fixing $T_{ADAPD} = 0$ or $T_{ADAPA} = 0$, or both. T_{ADAPD} (T_{ADAPA}) shall also be dynamically varied in order to reject CW interference as specified in 3.4.3.2.5.1.

3.4.3.4.5.1.3 Sensitivity Time Control (STC). - The time varying thresholds T_{STCD} and T_{STCA} shall be provided for use in some situations to minimize occurrence of false replies arising from reflections. These thresholds shall be site adaptable.

The threshold T_{STCD} is applicable for reception of Mode S replies. Following a Mode S Roll-Call interrogation, T_{STCD} shall conform within ± 3 dB to:

$$T_{STCD}(t) = \begin{cases} C1 & \text{for } t \leq 140.35 \\ C1 - 20 \log \frac{t - 128.0}{12.35} & \text{for } t > 140.35 \end{cases}$$

t - a fixed time in microseconds that represents the time from the sync phase reversal to the expected time of each reply. The above expression is valid for all values of t up to the point at which T_{STCD} becomes negative. T_{STCD} remains fixed for the entire length of the reply window. T_{STCD} shall remain fixed at the value T_{STCD} at range p_e where p_e is the earliest expected range of each reply (3.4.6.10.4.3). $C1$ is a parameter, adjustable in steps no greater than 1 dB over the range 0 to 55 dB. Following an ATCRBS/Mode S All-Call interrogation, or a Mode S-only All Call interrogation, T_{STCD} shall conform within ± 3 dB to:

$$T_{STCD}(t) = \begin{cases} C2 & \text{for } t \leq 140.35 \\ C2 - 20 \log \frac{t - 128.0}{12.35} & \text{for } t > 140.35 \end{cases}$$

For an ATCRBS/Mode S All-Call interrogation, t - time in μ s after the leading edge of interrogation pulse P4 up to the point at which this expression becomes negative. For a Mode S-Only All-Call interrogation, t - time in μ s after the sync phase reversal up to the point at which this expression becomes negative. $C2$ is a parameter adjustable in steps no greater than 1 dB over the range 0 to 55 dB.

The threshold T_{STCA} is applicable for reception of ATCRBS replies. Following an ATCRBS/Mode S All-Call interrogation, an ATCRBS-only All Call interrogation, or an ATCRBS interrogation, T_{STCA} shall conform within ± 3 dB to:

$$T_{STCA}(t) = \begin{cases} C3 & \text{for } t \leq 15.35 \\ C3 - 20 \log \frac{t - 3.0}{12.35} & \text{for } t > 15.35 \end{cases}$$

t = time in μs after the leading edge of interrogation pulse P3 up to the point at which this expression becomes negative. C3 is a parameter, adjustable in steps no greater than 1 dB over the range 0 to 55 dB.

3.4.3.4.5.2 Quantized sum slope. - The quantized slope signals are used to indicate when the slope of the Σ signal exceeds a preset rate in the positive direction and in the negative direction. The quantized positive slope signal is denoted by Q Σ PS and is defined as follows:

$$Q\sum PS = \begin{cases} 1 & \text{whenever } |\Sigma(t)|/|\Sigma(t-d)| > T_{PS} \\ & \text{(or equivalently, when } \log |\Sigma(t)| - \log |\Sigma(t-d)| > \log T_{PS}) \\ 0 & \text{otherwise.} \end{cases}$$

The quantized negative slope signal is denoted by Q Σ NS and is defined as follows:

$$Q\sum NS = \begin{cases} 1 & \text{whenever } |\Sigma(t-d)|/|\Sigma(t)| > T_{NS} \\ & \text{(or equivalently, when } \log |\Sigma(t-d)| - \log |\Sigma(t)| > \log T_{NS}) \\ 0 & \text{otherwise} \end{cases}$$

The value of the delay d shall be 125 ± 10 ns. The nominal values of the threshold parameters T_{PS} and T_{NS} shall be 2.0 (6 dB per 125 ns), with provision to adjust these parameters over a range of 1.5 to 4.0.

3.4.3.4.5.3 Quantized sidelobe - suppressed video. - The $\log |\Sigma|$, $\log |\Delta|$, and $\log |\Omega|$ video signals shall be used to derive the quantized, sidelobe-suppressed video signals (denoted QSLSD and QSLSA) defined as follows:

$$QSLSD = \begin{cases} 1 & \text{whenever } \log |\Sigma| - \log |\Omega| > \log T_{\Omega} \text{ and} \\ & \log |\Sigma| - \log |\Delta| > \log T_{\Delta} \text{ and} \\ & \log |\Sigma| > \log T_{\Sigma D}, \\ 0 & \text{otherwise} \end{cases}$$

$$QSLSA = \begin{cases} 1 & \text{whenever } \log |\Sigma| - \log |\Omega| > \log T_{\Omega} \text{ and} \\ & \log |\Sigma| - \log |\Delta| > \log T_{\Delta} \text{ and} \\ & \log |\Sigma| > \log T_{\Sigma A}, \\ 0 & \text{otherwise} \end{cases}$$

The threshold parameters T_{Ω} and T_{Δ} shall have nominal values of 1 (0 dB), and provisions shall be made to manually adjust T_{Ω} over the range corresponding to $|\Sigma|/|\Omega|$ ratios from +20 dB to -10 dB and T_{Δ} over the same range of $|\Sigma|/|\Delta|$ ratios.

3.4.3.5 Auxiliary video output channel.

3.4.3.5.1 IF bandpass filter. - The detailed requirements of the IF filter for the auxiliary video output channel are given below:

a. Frequency Response

IF Frequency	60 MHz
Bandwidth	Flat to within 1 dB from 57 MHz to 63 MHz ≥ 8 MHz at -3 dB points ≤ 18 MHz at -40 dBm points

b. Pulse Response

Same as 3.4.3.4.2(b) except the fall time shall be measured from the 3dB point to the 20 dB point.

3.4.3.5.2 Logarithmic amplifier/detector.- The logarithmic amplifier/detector for the auxiliary video output channel shall have the same characteristics as 3.4.3.4.4.

3.4.3.5.3 Video quantizer.- The video quantizer in the auxiliary video output channel shall operate on the auxiliary $|\Sigma|$ video signal to produce an output signal quantized in amplitude to two levels. The transition time between levels shall be no more than 20 ns.

3.4.3.5.3.1 Quantized auxiliary sum video.- The quantized auxiliary sum video signal (denoted Aux $Q\Sigma$) shall be derived from the Aux Log $|\Sigma|$ video signal according to the rules specified for $Q\Sigma A$ in paragraph 3.4.3.4.5.1.

3.4.3.5.3.2 Detection threshold.- The detection threshold for the auxiliary sum video signal (denoted Aux T_Σ) shall be the greater of three terms

$$\text{Aux}T_\Sigma = \text{MAX}(\text{Aux}T_F, \text{Aux}T_{\text{ADAP}}, \text{Aux}T_{\text{STC}})$$

$\text{Aux}T_F$, $\text{Aux}T_{\text{ADAP}}$ and $\text{Aux}T_{\text{STC}}$ shall have the same characteristics as specified for T_{FA} , T_{ADAPA} and T_{STCA} respectively in paragraphs 3.4.3.4.5.1.1 through 3.4.3.4.5.1.2.

3.4.3.5.4 Video output.- The video from the auxiliary video output channel shall be selectable between the ATCRBS log sum quantized video (Log $|\Sigma|$ video in Fig. 3.4.3-2) and the auxiliary log sum quantized video (Aux $|\Sigma|$ video in Fig. 3.4.3-2). The selection shall be accomplished by means of a variable site selectable parameter. Four independently quantized auxiliary video outputs and a log auxiliary video output shall be provided from the interrogator video outputs and a log auxiliary video output shall be provided from the interrogator channel. Each output shall be electrically isolated so that a short or failure in one output shall not affect the other outputs. Each quantized auxiliary video output shall comply with the electrical characteristics of EIA RS-422 Standard.

Overshoot and undershoot on the video pulses shall be less than 5 percent.

The log video output shall be provided by a line driver capable of driving 75 ohms. Pulse characteristics shall be as specified in 3.4.3.4.4.

This page intentionally unused.

3.4.4 Mode S reply processing.- The Mode S processing subsystem shall process the multichannel receiver output signals to detect Mode S roll-call and All-Call replies, to provide range and monopulse estimates, and decode message blocks for both types of replies. The inputs to the Mode S processing subsystem from the multichannel receiver are:

- (a) Log Σ video.
- (b) Quantized video signals (QED, QEPS, QENS, QSLSD).
- (c) Monopulse video (ϕ).

In addition, the Mode S processing subsystem requires the following inputs:

- (d) Station time clock, continuously available (3.4.13.3).
- (e) Time-of-day clock (3.4.13.2.2).
- (f) Antenna boresight azimuth encoder, continuously available (14 bits).
- (g) Reply-type indicator (All-Call or roll-call).
- (h) Roll-call reply processing information, (Fig. 3.4.4-12a):
 - Reply length (56 or 112 bits);
 - Expected Mode S address;
 - Earliest expected time of arrival (range unit word, 3.4.13.3.2)
 - Reply window (3.4.1.5.4.4.1(7))
- (i) All-Call reply processing information (Fig. 3.4.2-1(d)).
 - Transmission time of the interrogation (range unit word, 3.4.13.3.2).
 - Listening window (3.4.1.2.3.4)
 - Site address for Mode S-Only All-Call (Mode S National Standard).

The output of the Mode S processing subsystem shall consist of reply reports, one per detected All-Call reply and one per scheduled roll-call reply. Each reply report shall contain the following information:

- (a) Range (for All-Call replies) or range correction (for roll-call replies) (range unit word, 3.4.13.3.2).
- (b) Monopulse estimate (3.4.4.2.5).
- (c) Antenna boresight azimuth encoder (14 bits).
- (d) Time of day for the reply (3.4.13.2.2).
- (e) Decoded message (for successfully decoded replies) (32 or 88 bits)
- (f) Failure indication (for unsuccessful roll-call reply processing) (3.4.4.8.2(b)).

3.4.4.1 Major subunits of the Mode S processor.- A functional block diagram of the Mode S processing subsystem is shown in fig. 3.4.4-1. The major sub-units of the processor shall be:

- (a) Video digitizer.
- (b) Preamble detector.
- (c) Message bit processor.

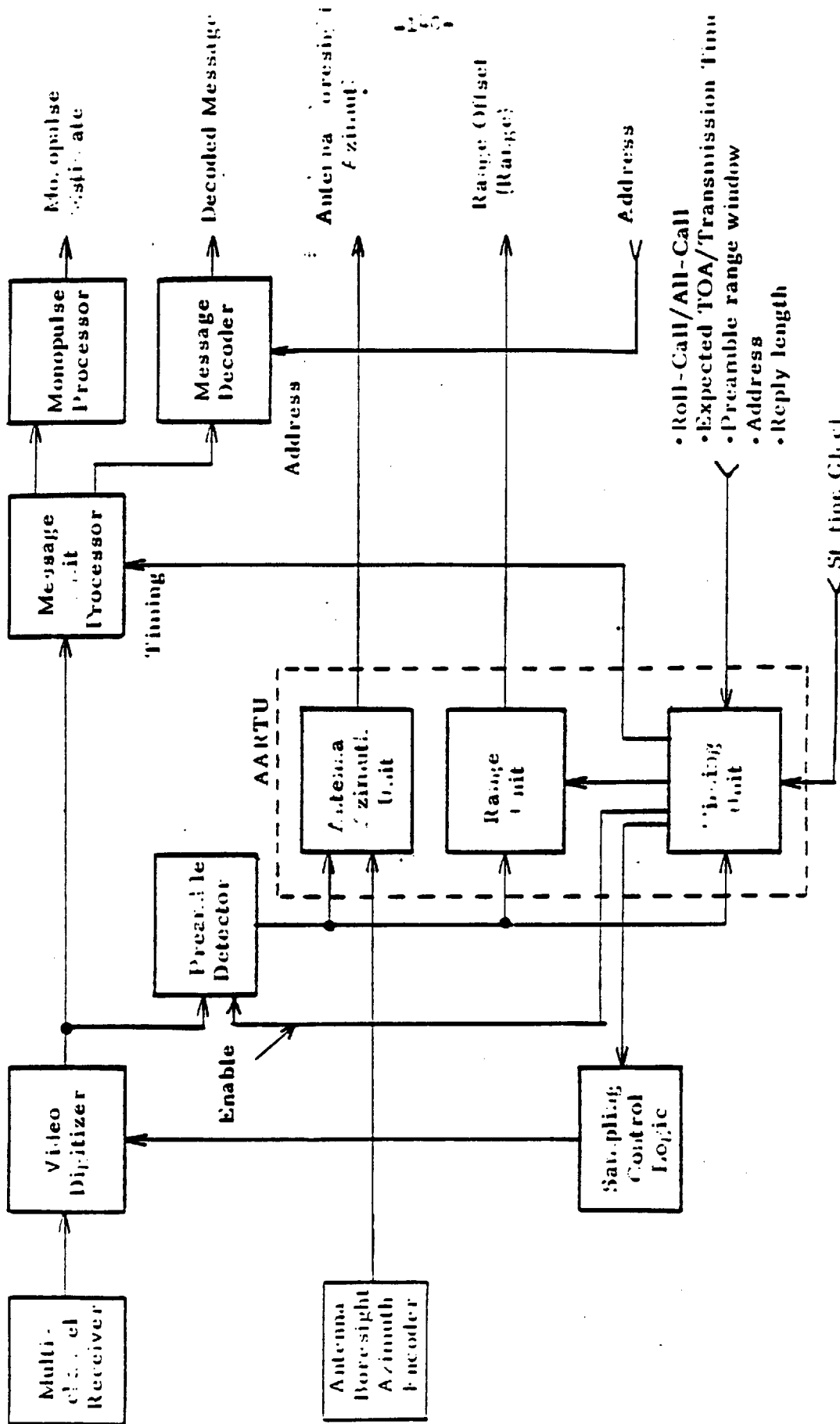


FIGURE 3.6.4-1. THERMAL BLOCK DIAGRAM OF MODE 5 PROCESSING SUBSYSTEMS

- (d) Message decoder.
- (e) Monopulse processor.
- (f) Antenna azimuth-range-timing unit.

The design requirements of each of these subunits are specified in the following paragraphs.

3.4.4.2 Video digitizer.- The function of the video digitizer is to provide digital data in appropriate format for reply detection and processing. A functional block diagram of the video digitizer is shown in fig. 3.4.4-2.

3.4.4.2.1 Video pulse quantizer/digitizer.- The video pulse quantizer/digitizer (VPQ) circuit shall operate on the three quantized video signals derived from $\log |Z|$, namely, the QED, QEPS, and QENS signals, to produce a clocked binary data stream which faithfully preserves the width of pulses with amplitudes greater than a specified threshold. The output data stream of the VPQ, denoted SQED, shall be clocked at 16.000 MHz and shall drive the Mode S preamble detector circuit.

3.4.4.2.1.1 Leading edge declaration.- The VPQ circuit shall declare a pulse "leading edge" at time t_1 , signified by a transition of its next output binary digit from the "0" state to the "1" state, whenever all of the following conditions are satisfied simultaneously.

- (a) $QED(t_1 + d) = 1$
- (b) $QEPS(t_1) = 1$
- (c) $QEPS(t_1 + d) = 0$

The time delay, d , shall be two 16.000 MHz clock periods.

3.4.4.2.1.2 Trailing edge declaration.- The VPQ shall declare a trailing edge at time t_2 , signified by a transition of its next output binary digit from the "1" state to the "0" state, if its output is in the "1" state and

$$QED(t_2) = 0.$$

The VPQ shall declare a potential trailing edge at time t_2 , if its output is in the "1" state, whenever the following conditions are satisfied simultaneously:

- (a) $QENS(t_2 - d) = 0$
- (b) $QENS(t_2) = 1$

The parameter d is the same as specified in paragraph 3.4.3.4.5.2. A potential trailing edge at time t_2 shall be declared an actual trailing edge if:

- (a) $QED(t_2 + d) = 0$, or
- (b) $QEPS(t_2 + d) = 1$, or

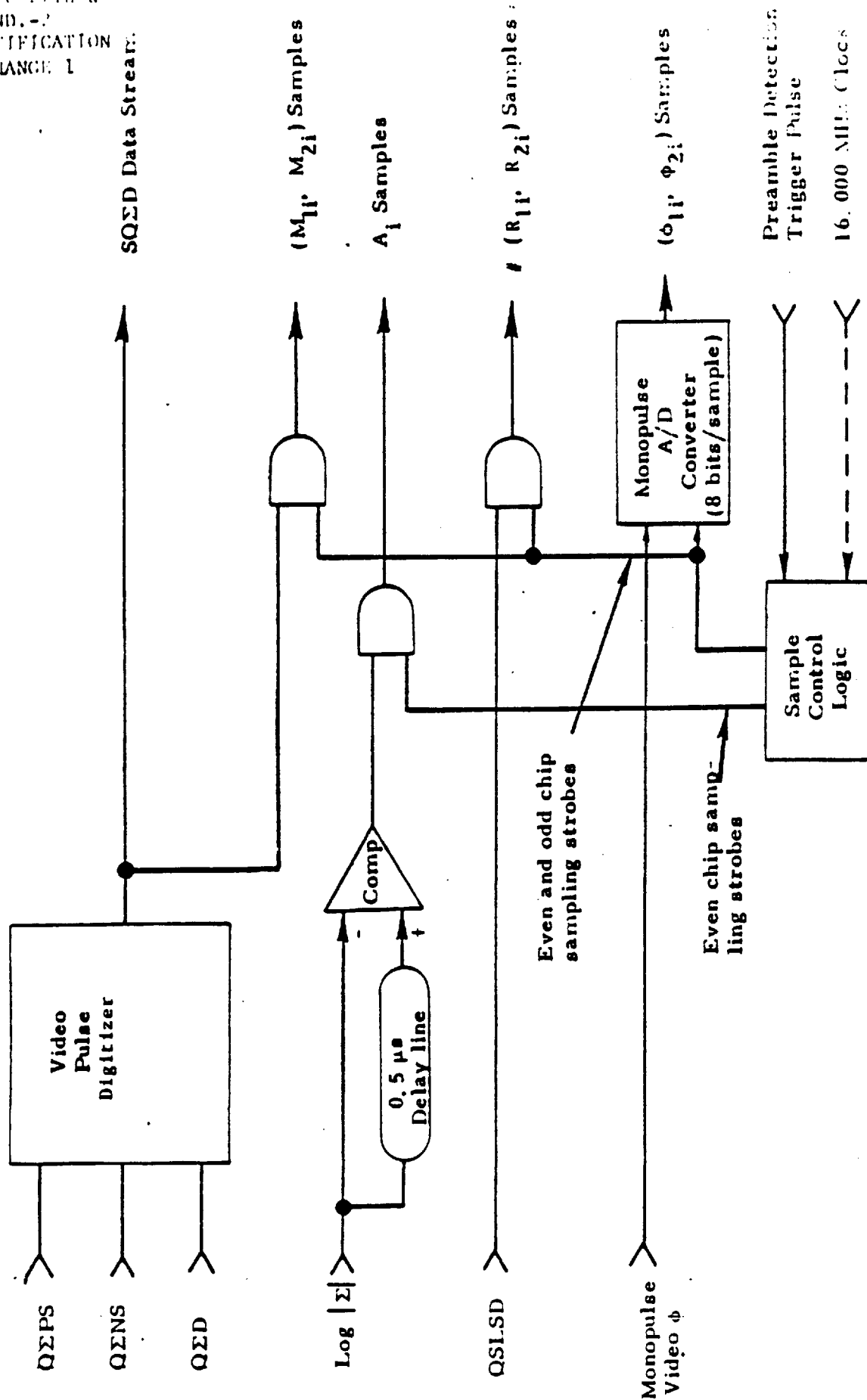


FIGURE 3.4.4-2
 MODEL S VIDEO DIGITIZER

- (c) $QENS(t_2 + d) = 1$, and $QED(t_2 + 2d) = 0$, or
- (d) $QENS(t_2 + d) = 1$, and $QEPS(t_2 + 2d) = 1$, or
- (e) $QENS(t_2 + d) = 1$, and $QENS(t_2 + 2d) = 1$.

3.4.4.2.2 Sampling control logic.— Upon receipt of a trigger pulse denoting detection of a Mode S preamble, and a reply length indicator bit (denoted L), the sampling control logic circuitry shall generate a sequence of sampling control pulses to be used to control the instants at which the digitized video signals SQED and QSLSD, monopulse video (ϕ) and Log | Σ | amplitude comparison signals are sampled for processing a Mode S reply data block. For short replies (L=0) a sequence of 112 sampling control pulses shall be generated to sample the reply block once per chip (twice per bit interval). For long replies (L=1), a sequence of 224 sampling control pulses shall be generated.

A data block chip is defined as one half of the 1.0 μ sec interval corresponding to a reply message data bit. A pulse transmitted in the 1st half of the interval (1st chip) denotes a bit level of "1". A pulse transmitted in the 2nd half (2nd chip) denotes a bit level of "0".

The timing of the sampling control pulses relative to the preamble detection trigger pulse shall be such that each data block chip is sampled 375 ns after its expected leading edge time of occurrence (as determined from the leading edge sample of the first preamble pulse in the SQED data stream). (See fig. 3.4.4-3). That is, the sampling of the video waveforms corresponding to the first chip of the data block shall occur 8.375 μ s (or 134 sample intervals) after the point on the Log | Σ | video waveform which corresponds to the '1' in the SQED data stream which represents the leading edge of the first preamble pulse of the just detected preamble.

Provision shall be made to manually change the start time of the data block sampling to lie anywhere in the range 134 ± 3 sample intervals after the leading sample of the first preamble pulse.

It is intended that the sampling control logic provide for samples of the video waveforms that fall within the 0.2 μ s monopulse sampling window of each chip described in 3.4.3.2.3.

3.4.4.2.3 Quantized sum video digitizer.— Upon detection of a Mode S preamble, an output shall be generated by the quantized sum video digitizer under control of the sampling control logic described in 3.4.4.2.2. The resulting output is one sample per data block chip, with the sampling instants occurring nominally at 375 ns (6 sample intervals) after the expected leading edge of each chip, as determined from the leading edge sample of the first preamble pulse in the SQED data stream (3.4.4.2.2).

The data block samples of the quantized sum video digitizer corresponding to the first and second chips of the i th information bit of the data block will be denoted by M_{1i} and M_{2i} , respectively.

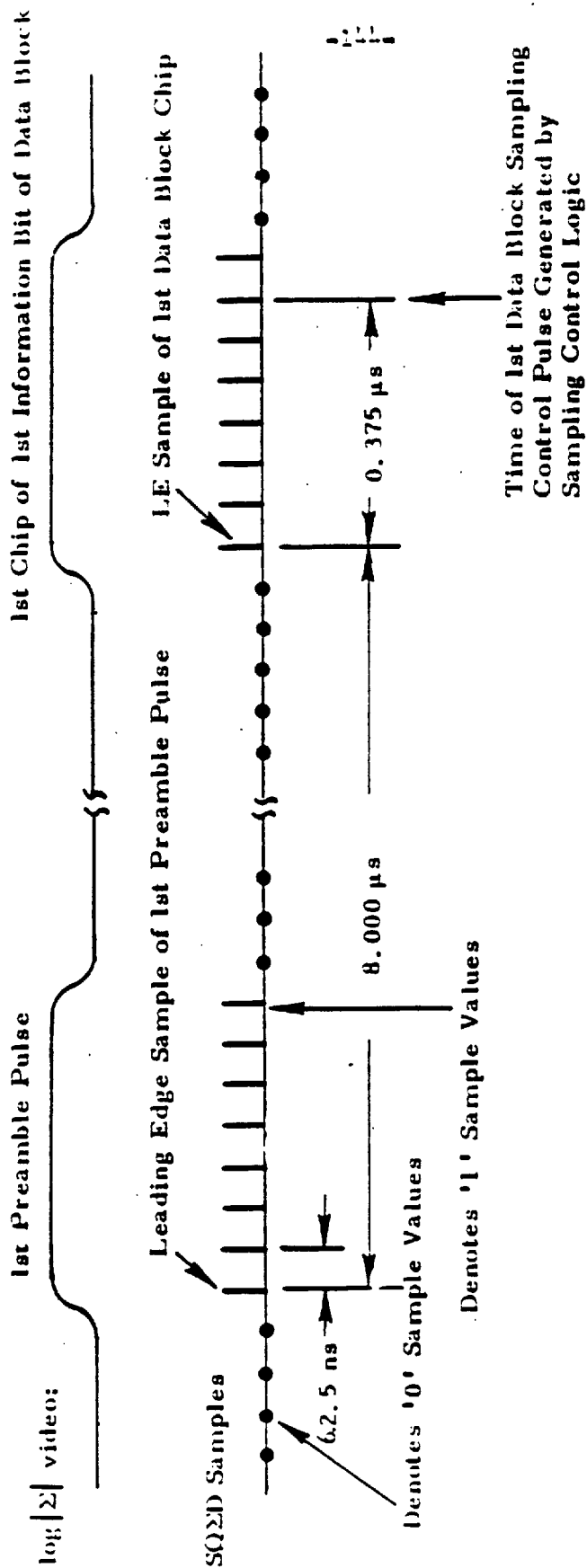


FIGURE 3.4.4-3

DATA BLOCK SAMPLE TIMING RELATIVE TO PREAMBLE

3.4.4.2.4 Quantized SLS video digitizer.- The two level video waveforms QSLSD provided by the log video comparator (3.4.3.4.5.3) shall be sampled once per data block chip with the exact sampling instant controlled by the sampling control logic (3.4.4.2.2). The resulting sample values shall be binary, with a 0 denoting the QSLSD signals which are sidelobe pulses and a 1 denoting mainbeam pulses.

The output samples of the quantized SLS video digitizer corresponding to the first and second chips of the i th information bit of the data block will be denoted by R_{1i} and R_{2i} , respectively.

3.4.4.2.5 Monopulse digitizer.- The monopulse video channel shall be sampled once per data block chip with the exact sampling instant controlled by the sampling control logic (3.4.4.2.2).

The monopulse sample values shall be represented as 8 bit words, i.e., the monopulse video signal shall be converted to one of 256 levels denoted by the integers from 0 to 255, with increasing sample values corresponding to off-boresight angles going from left to right. Provision shall be made to adjust the monopulse video channel gain prior to the A/D converter so that the range of off-boresight angles corresponding to antenna pattern gain ratios

$$-2 \leq \frac{\Delta}{\Sigma} \leq 2$$

are converted to the 237 levels in the center of the full range of 256 output levels.

That is, the off-boresight angle corresponding to $\frac{\Delta}{\Sigma} = -2$ shall be converted to level 10 and $\frac{\Delta}{\Sigma} = 2$ shall be converted to level 246.

The monopulse samples corresponding to the first and second chips of the i th information bit of the block will be denoted by ϕ_{1i} and ϕ_{2i} , respectively.

3.4.4.2.6 Amplitude comparison digitizer.- The $\text{Log} |\Sigma|$ video input signal shall be compared for both chips corresponding to an information bit of the data block. This amplitude comparison may be done as shown in fig. 3.4.4-2 using a $0.5 \pm 0.03 \mu s$ delay line and a digital comparator. The output of the digital comparator shall be sampled once per information bit with the exact sampling instant controlled by the even chip samples of the sampling control pulses provided by the sampling control logic. The resulting samples shall be binary valued, with 1 used to denote when the amplitude of the first chip is larger than the second chip, corresponding to a '1' information bit.

The amplitude comparator sample corresponding to the i -th information bit of the data block will be denoted by A_i .

3.4.4.3 Preamble detector.- The Mode S preamble detector processes only the SQΣD binary data stream and produces as its output a precisely timed trigger pulse which shall be used to determine range and to establish the exact timing of the data block sampling. The preamble detection trigger pulse shall be inhibited except during the All-Call listening interval and during roll-call preamble listening windows. Preamble trigger pulses shall also be inhibited for the duration of the data block following detection of any Mode S preamble.

3.4.4.3.1 Preamble detection criterion.- A Mode S preamble shall be declared when valid pulses are detected in all four positions of the preamble waveform and, in addition, at least two of the pulses are detected with clear leading edges. A valid pulse is defined to be one in which at least k out of 8 successive samples of the SQΣD data stream are '1'. (The parameter k shall be manually settable to values 4, 5, 6, 7 or 8.) A clear leading edge is defined as a valid pulse for which the SQΣD sample preceding the 8 samples of the pulse is a '0' and the first of the 8 samples of the pulse is a 1. The position of a pulse is defined as the location of the first of the eight successive samples corresponding to the pulse.

A Mode S preamble shall be declared when a valid pulse is followed by three additional valid pulses located 16, 56, and 72 sample positions after the position of the first pulse and, in addition, at least two of the four valid pulses have clear leading edges which are in agreement with the above spacings within ± 2 samples.

If no preamble is detected within a preamble processing window, the Mode S reply processor shall output a signal to denote this event in the reply report.

3.4.4.3.2 Time-of-arrival estimation.- The time-of-arrival of a Mode S preamble (denoted t_2) shall be taken to be the position of the (leading edge sample of the) first preamble pulse. The preamble detection trigger pulse shall occur at a known, fixed delay following the preamble time-of-arrival. This delay shall be used in determining a target range estimate (r) for All-Call replies, or target range correction (Δr) for roll-call replies.

3.4.4.4 Message bit processor.- The message bit processor shall process the video digitizer outputs corresponding to a sampled data block and produce a sequence of information bit decisions and a corresponding sequence of confidence bits. The lengths of these sequences shall be 56 or 112 bits, depending on the reply length indicator bit L, also input to the bit processor. For each information bit of the data block processed, the bit processor shall operate on the inputs:

- (a) A_1 , amplitude comparison sample.
- (b) M_{11} , M_{21} , quantized sum video chip samples.
- (c) R_{11} , R_{21} , quantized SLS video chip samples.

and shall produce the two output bits:

- (a) D_i , the information bit decision,
- (b) C_i , the confidence bit ('1' = high, '0' = low).

3.4.4.4.1 Information bit decision rule.— The bit decision rules for D_i are given in Table 3.4.4-1. These rules may be summarized as follows: The bit decision shall be governed by the value of the amplitude comparison sample A_i except when the SLS video samples contradict this decision and the quantized Z samples indicate pulses present in both chip positions, in which case, the bit decision shall be governed by the SLS video samples ($D = 1(0)$ if $R_{1i} = 1(0)$ and $R_{2i} = 0(1)$ and $M_{1i} = M_{2i} = 1$).

Boolean expressions for D_i , which are consistent with Table 3.4.4-1 are as follows. (The symbol \oplus is used to denote the logical 'exclusive OR' operation, which is the same as the binary sum Modulo 2 operation.)

$$D_i = A_i \oplus [(M_{1i} \cdot M_{2i}) \cdot (R_{1i} \oplus R_{2i}) \cdot (A_i \oplus R_{1i})].$$

3.4.4.4.2 Confidence bit rule.— The confidence bit rule for C_i in which high confidence is denoted by '1', is given in Table 3.4.4-1. The Boolean expression for C_i , which is consistent with the table, is

$$C_i = (\bar{A}_i \cdot \bar{M}_{1i} \cdot M_{2i} \cdot \bar{R}_{1i} \cdot R_{2i}) + (A_i \cdot M_{1i} \cdot \bar{M}_{2i} \cdot R_{1i} \cdot \bar{R}_{2i}).$$

3.4.4.5 Monopulse processor.— The monopulse estimate for a reply shall be formed as the average of 16 acceptable monopulse samples 15 of which correlate with a monopulse reference derived using two acceptable, monopulse samples.

The monopulse sample taken on the first chip of the i th information bit is defined as an acceptable sample if the following conditions are true:

$$\left. \begin{array}{l} \text{1st chip} \\ \text{acceptable} \end{array} \right\} \begin{array}{l} \text{(a) } D_i = 1 \\ \text{(b) } C_i = 1 \end{array}$$

The monopulse sample taken on the second chip of the i th information bit is acceptable if the following conditions are true:

$$\left. \begin{array}{l} \text{2nd chip} \\ \text{acceptable} \end{array} \right\} \begin{array}{l} \text{(a) } D_i = 0 \\ \text{(b) } C_i = 1 \end{array}$$

These rules are included in Table 3.4.4-1.

TABLE 3.4.4-1 MODE S BIT PROCESSING DECISION RULES.

A ₁	M ₁₁	M ₂₁	R ₁₁	R ₂₁	Bit Decision D ₁	Confidence Bit C ₁	Monopulse Acceptable (Chip 1 or 2)	Remarks†
0	0	1	0	0	0	0	-	Chip 2 with SL interferer
0	0	1	0	1	0	1	2	Interference Free
0	0	1	1	0			*	
0	0	1	1	1			*	
0	1	1	0	0	0	0	-	Both chips with SL interferers
0	1	1	0	1	0	0	-	Chip 1 with SL interferer
0	1	1	1	0	1	0	-	Chip 2 with SL interferer
0	1	1	1	1	0	0	-	Signal + MB interferer
0	1	0	0	0	0	0	-	Both chips with SL interferers
0	1	0	0	1			*	
0	1	0	1	0	0	0	-	Both chips with interferers
0	1	0	1	1			*	
0	0	0	0	0	0	0	-	Chip 2 with interference
0	0	0	0	1			*	
0	0	0	1	0			*	
0	0	0	1	1			*	
1	1	0	0	0	1	0	-	Chip 1 with SL interferers
1	1	0	0	1			*	
1	1	0	1	0	1	1	1	Interference Free
1	1	0	1	1			*	
1	1	1	0	0	1	0	-	Both chips with SL interferers
1	1	1	0	1	0	0	-	Chip 1 with SL interferer
1	1	1	1	0	1	0	-	Chip 2 with interferer
1	1	1	1	1	1	0	-	Signal + MB interferer
1	0	1	0	0	1	0	-	Both chips with SL interferers
1	0	1	0	1	1	0	-	Both chips with interferers
1	0	1	1	0			*	
1	0	1	1	1			*	
1	0	0	0	0	1	0	-	Chip 1 with interference
1	0	0	0	1			*	
1	0	0	1	0			*	
1	0	0	1	1			*	

*Impossible case, by definition of QSLSD from which R₁₁; R₂₁ were derived.

†Abbreviations: SL = Sidelobe, MB = Main Beam.

A monopulse reference is defined as the average of two successive acceptable monopulse samples which are within K counts of each other (the parameter K shall be manually settable and of value 20(0-63,1)). That is, two monopulse samples are said to be correlated with each other if their 8-bit sample values, taken as integers from 0 to 255, differ by K or less. Thus, a monopulse reference shall be taken as the average of the first pair of successive, acceptable monopulse samples which correlate within K counts.

The monopulse estimate for the reply shall be taken as the average of the monopulse reference and the first 15 acceptable samples which correlate within K counts with the reference following the establishment of the monopulse reference. If the monopulse reference is never established, or if an insufficient number of acceptable monopulse samples are available after the establishment of the monopulse reference, this failure condition shall be indicated in the reply report (3.4.4.8.2).

3.4.4.6 Message decoding.- The function of message decoding is to first check the bit decision sequence for errors by means of a parity check, and if errors are detected, to then use the confidence bit sequence to attempt to locate a burst error pattern spanning up to 24 bit decisions that would correct the message. The inputs to the message decoder are:

- (a) Bit decision sequence (D_i).
- (b) Confidence bit sequence (C_i).
- (c) Reply length indicator bit (L).
- (d) Expected address (\bar{A}_i , $i = 1, \dots, 24$).

The decoder outputs are:

- (a) Successful decode indication bit, m (1 bit).
- (b) The decoded message, if m = 1 (32 or 88 bits).

The decoding polynomial is given by:

$$G(x) = \sum_{j=0}^{24} g_j x^j$$

where $g_j = 1$ for $j = 0, 3, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24$
 $g_j = 0$, otherwise.

Message decoding will be treated in three stages; error detection, error pattern location, and error correction.

3.4.4.6.1 Error detector.- The primary function of the error detector is to compute a 24 bit error syndrome. This computation shall be accomplished in two steps. First, the decoded address shall be calculated from the sequence of bit decisions. Then the syndrome shall be obtained by a comparison of the decoded address with the expected address. If the two addresses agree, then the error syndrome shall be zero (i.e., all component bits are zero), and the decoded message will ultimately be obtained directly from the bit decision sequence.

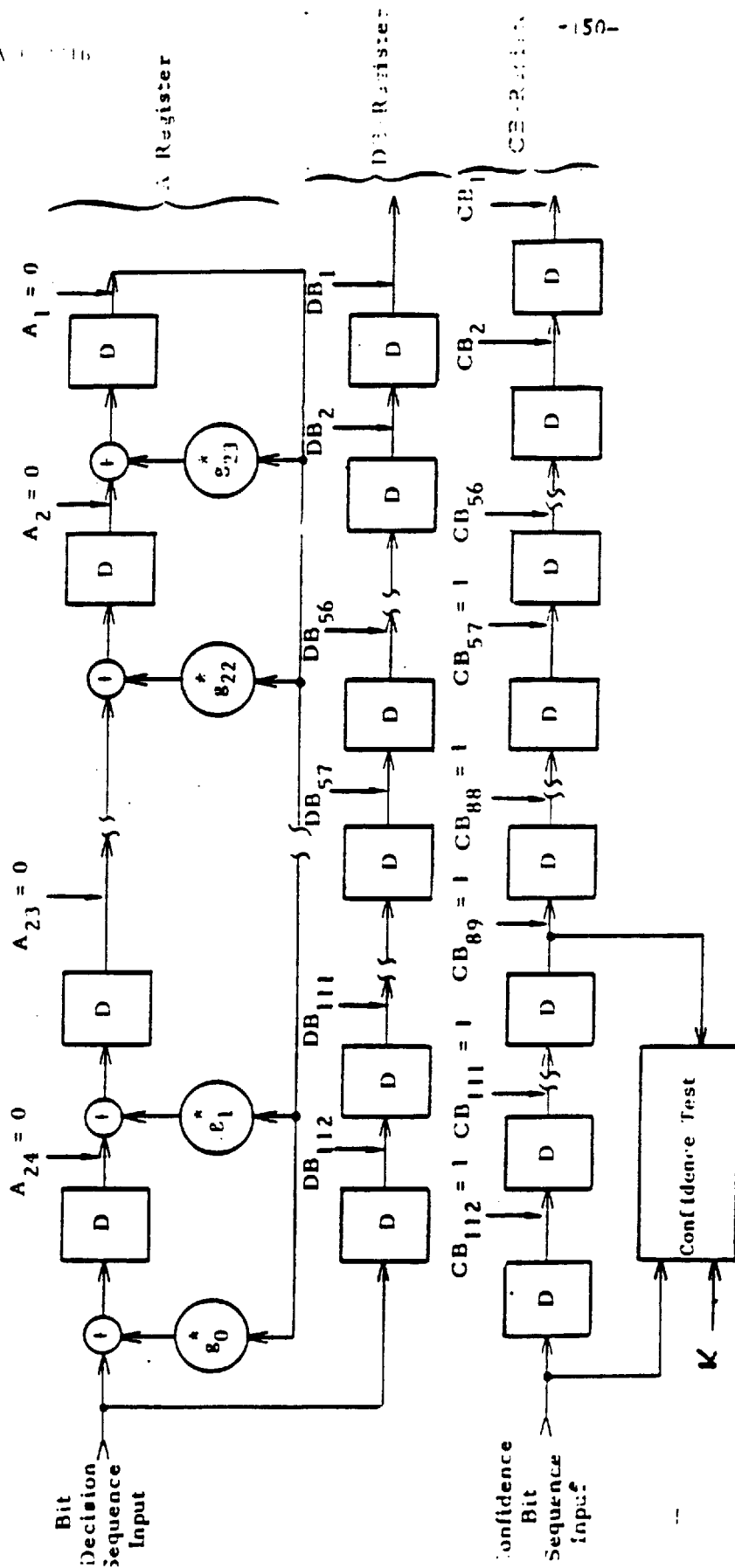


FIGURE 3.4.4-4
INITIAL CONDITIONS FOR ERROR DETECTION

3.4.4.6.1.1 Initial conditions for error detector.- The error detector and initial conditions are shown in fig. 3.4.4-4. The DB register is used to store the bit decision sequence as it is produced by the bit processor and need not be initialized. The CB register is used to store the confidence bit sequence as it is produced by the bit processor and shall be initialized by setting the 56 stages closest to the input to '1'. The A-register, used to determine the decoded address A_i , $i = 1, \dots, 24$, shall be initialized by resetting all 24 stages to '0'.

3.4.4.6.1.2 Confidence test.- As the confidence bits are being loaded into the CB register a confidence test shall maintain a count of the number of high-confidence bits contained in the 24 elements closest to the input side of the register. (Note: The count shall be initialized to 24). If the counter falls below a threshold K while the CB register is being loaded, the correction disable bit shall be set to '1'. Correction of an erroneous message shall not be allowed if the correction disable bit has been set. Provision shall be made for manual setting of the threshold K to any integer between 10 and 20.

3.4.4.6.1.3 Final conditions of error detector.- The bit processor shall produce sequentially the bit decision sequence in the order D_1, D_2, \dots, D_I and the confidence bit sequence in the order C_1, C_2, \dots, C_I , with C_i and D_i made available to the message decoder together after the i th information bit interval has been processed. The lengths of these sequences (I) is determined by the message length indicator bit L ($I = 56$ for $L = 0$, $I = 112$ for $L = 1$.) The bit decision sequence is shifted into the DB-register and the A-register as each bit decision is produced. The confidence bit sequence is shifted into the CB register and checked by the confidence test as each bit decision is produced. The state of the error detector immediately after the last bit decision and confidence bit is input to the message decoder, is shown in fig. 3.4.4-5(a) and (b). At this instant, the decoded address A_1, \dots, A_{24} is compared bit by bit with the expected address A_1, \dots, A_{24} to produce by parallel Modulo 2 addition, the 24 bit error syndrome denoted S_1, \dots, S_{24} .

3.4.4.6.1.4 Error detection criterion.- If the correction disable bit has been set, and the error syndrome is not all zeroes, error correction shall not be attempted, and this failure mode shall be indicated in the reply report for roll-call replies. If the correction disable bit is set and the error syndrome is all zeroes, the message shall be accepted. If the correction disable bit is not set, error correction will be attempted. The case in which the error syndrome is all zeroes shall be taken as an entirely correct bit decision sequence, but it is treated as a correctable error pattern in which no bit decisions are actually corrected.

3.4.4.6.2 Error location.- The second stage of message decoding attempts to locate a correctable error burst pattern in the bit decision sequence generated by the message bit processor. This function requires the error syndrome, and the confidence bit sequence.





FINAL CONDITIONS OF ERROR DETECTION LOGIC FOR L = 0(56 BIT REPLY)

Whenever the correction disable bit is not set, all of the erroneous bit decisions are confined within a segment of the bit decision sequence spanning no more than 24 bits, and none of the errors are associated with a high confidence bit, the error pattern is a correctable error pattern. In every instance of a correctable error pattern, the error correction circuit will generate a properly decoded message. However, when a correctable error pattern did not exist, the circuit will generate an erroneous message.

The error pattern location function shall attempt to locate erroneous bit decisions by performing logical operations on the syndrome and confidence bit sequence. If a correctable error pattern is located, a bit signifying such an occurrence shall be set. When set, this bit shall allow the corrections indicated by the error pattern to be made in the bit decision sequence by the error pattern correction function. If this bit, denoted by m and called the correction enable bit, has not been set after a specified number of operations have been performed, the erroneous bit decisions cannot be located by the error location function.

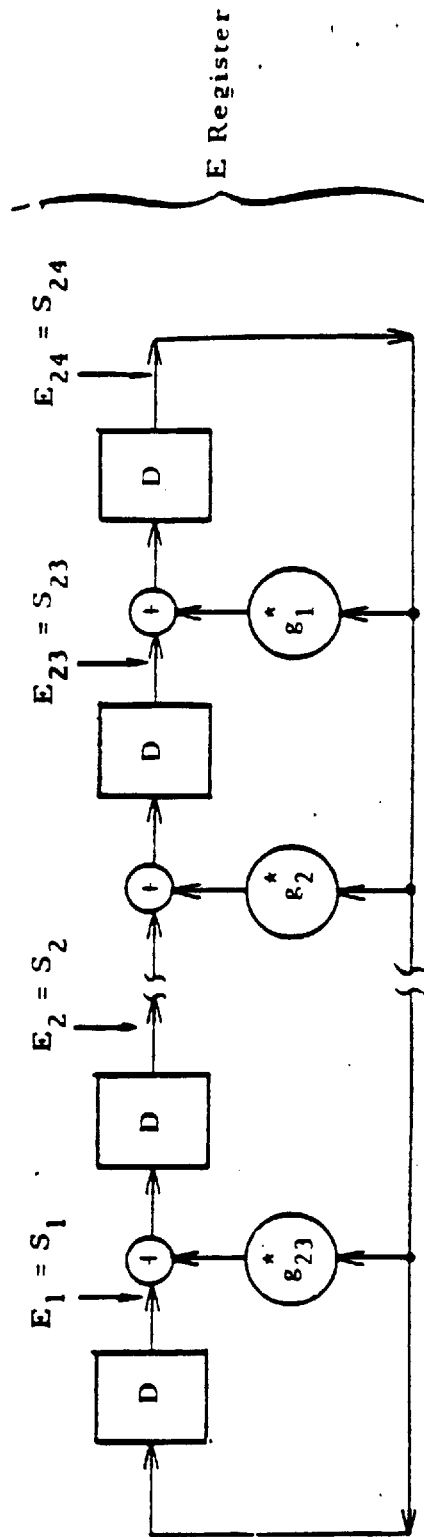
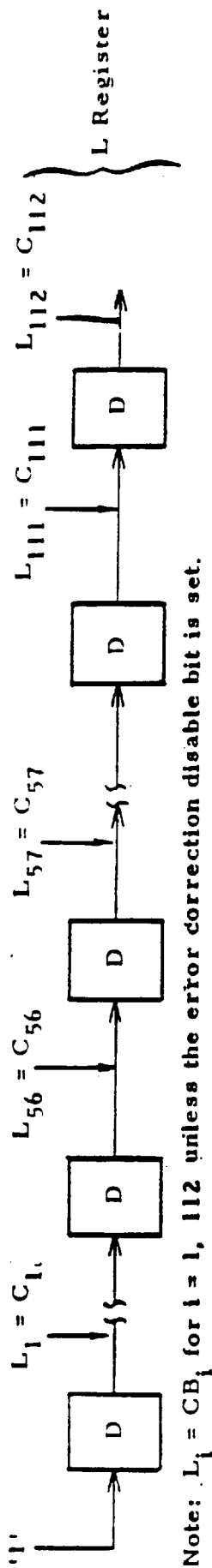
Whenever the calculated address agrees with the expected address, the syndrome is zero and, with very high probability, every bit in the decision sequence is correct. As a result of the syndrome being zero, the error location function will immediately find a correctable error pattern consisting of twenty-four zeroes. The correction enable bit will be set even though the error pattern has no effect on the bit decision sequence.

The final value of the correction enable bit shall be used to indicate the presence or absence of a decoded message.

3.4.4.6.2.1 Initialization of error pattern location function.- The error location function shall be initialized immediately after the error syndrome is generated by the error detector. The error location function requires three loading steps and is shown in fig. 3.4.4-6(a) and (b).

- (a) The E-register is loaded by a transfer of the error syndrome S_1, \dots, S_{24} .
- (b) The M-register is loaded by a transfer of the bit decision sequence D_1, \dots, D_I .
- (c) The L-register is loaded by a transfer of the confidence bit sequence C_1, \dots, C_I , unless the correction disable bit is set, whereupon the loading of the L-register is inhibited.

The loading of the M and L registers shall be done in such a way as to permit digits to be shifted out of these registers in the reverse of the order in which they were received from the message bit processor.



Same "g" values as figure 3.4.4.5

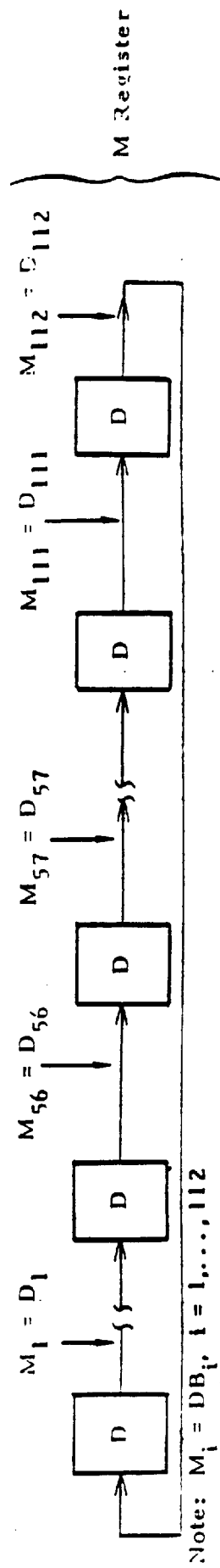
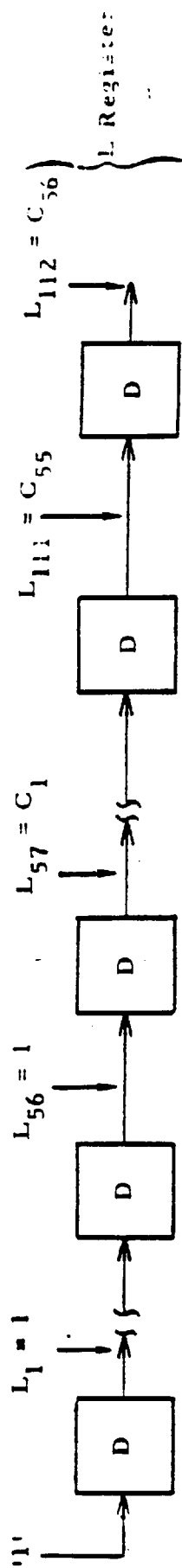
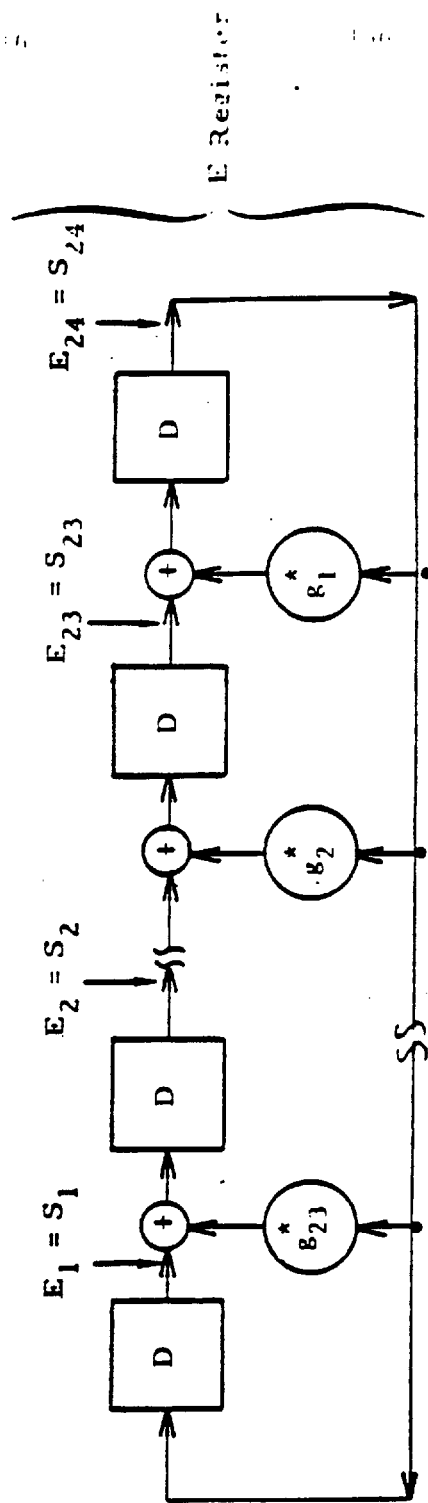


FIGURE 3.4.4-6(a)

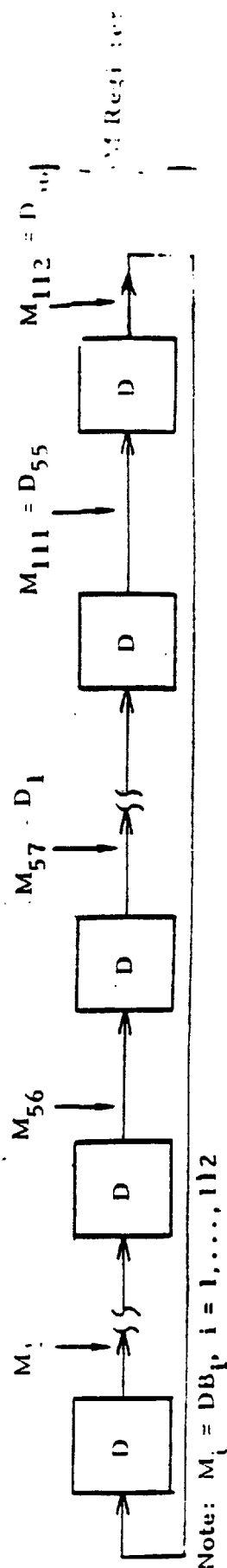
INITIALIZATION OF ERROR PATTERN LOCATION: LOGIC FOR $L = 1$ (112 BIT REPLY)



Note: $L_i = CB_i$, $i = 1, \dots, 112$ unless the error correction disable bit is set.



Same "g" values as figure 3.4.4.5



Note: $M_i = DB_i$, $i = 1, \dots, 112$

FIGURE 3.4.4-6(b)

INITIALIZATION OF ERROR PATTERN LOCATION LOGIC FOR $L = 0$ (56 BIT REPLY)

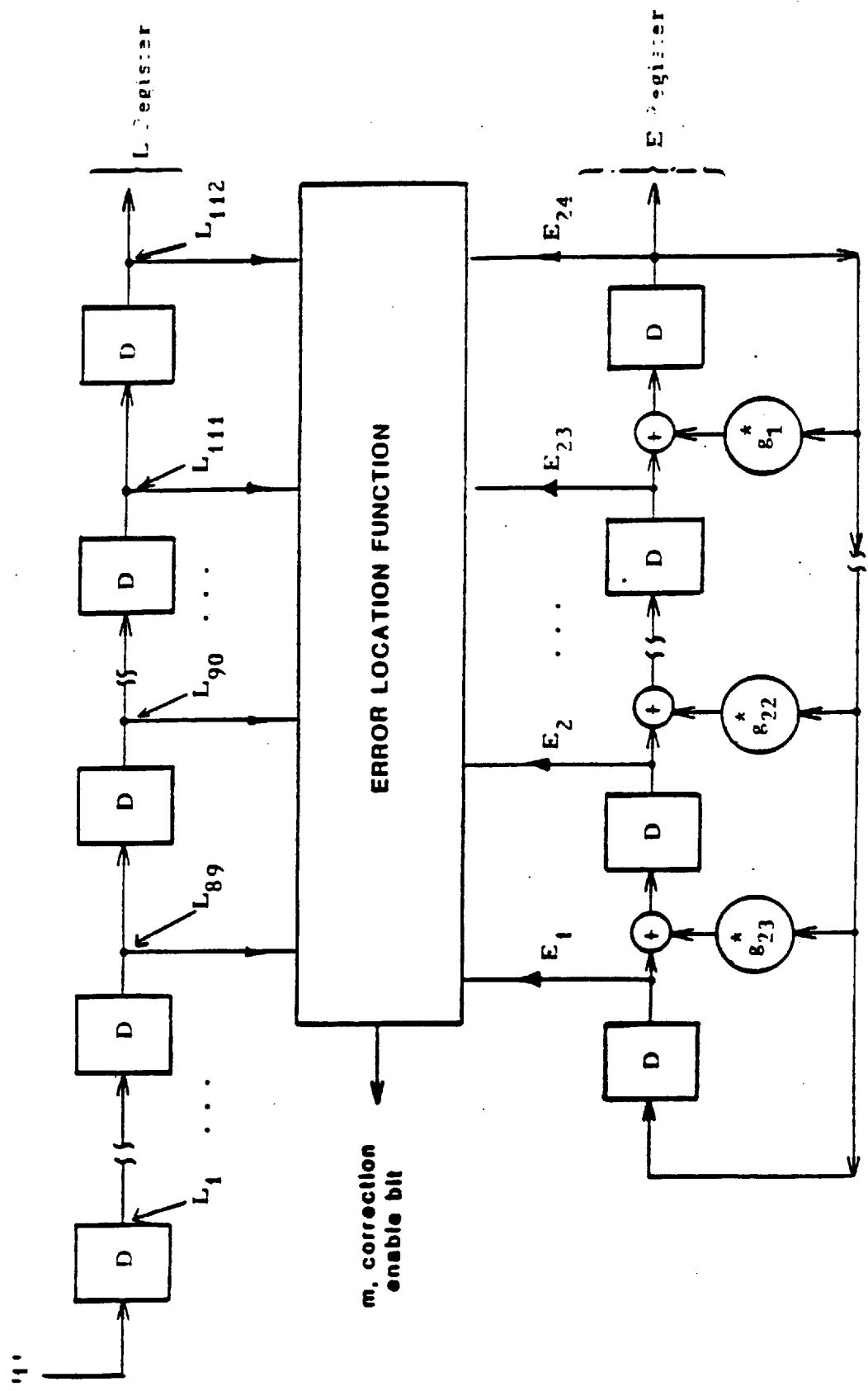
3.4.4.6.2.2 Correctable error pattern location.- Once initialized, the error location function (E, L, and M registers) shall be shifted simultaneously, as rapidly as practical to free the function for the next reply. (The error location function should complete the operation while the error detector is being loaded with data from the next reply.) The number of shifts performed shall be determined by the reply length indicator bit L (L = 0 implies 56 shifts, L = 1 implies 112 shifts). The input to the L-register shall continue to enter '1' in this register while the registers are being shifted. If, after the specified number of shifts, no correctable error pattern has been located, the registers shall be deactivated and this failure mode indicated in the reply report for roll-call replies.

The 24-bit E-register generates a sequence of possible burst error patterns as it is being shifted, each of which would result in the observed error syndrome. After initialization, the E-register contains a burst error pattern (which is the error syndrome itself) corresponding to the last 24 bits of the bit decision sequence.

After j shifts, the E-register contains a burst error pattern, which, if located in bits D_{I-j-23} through D_{I-j} , would result in the observed error syndrome. That is, every '1' in the E-register corresponds to a bit decision which is presumed to be in error, while every '0' in the E-register corresponds to a bit decision which is presumed to be correct. The E and L registers shall be shifted together so that the possible burst error patterns may be compared with the rightmost 24-bit segment of the confidence bit sequence.

If a burst error pattern is found in which all error locations ('1's in the E-register) align with low confidence bit positions ('0's in the L-register), a correctable error pattern has been located and a correction enable bit will be set to "1". (See fig. 3.4.4-7). The correction enable bit shall result in activation of the error pattern correction function.

3.4.4.6.3 Error correction.- Immediately after the correction enable bit has been set to '1' (before the next shift of the E, L and M registers), the error correction function shall be enabled to combine bit-by-bit the contents of the E-register with the contents of the M-register as shown in fig. 3.4.4-8. The next 24 shifts of the E and M registers then result in the error pattern being shifted out of the E-register (and replaced by zeroes), causing those bit decisions which are combined (sum Modulo 2) with '1's in the error pattern to be changed. The error location function has no effect after the error pattern is shifted out of the E-register, and so it is not necessary to disable this function. After the prescribed total number of shifts have been carried out, the state of the error correction function is as shown in fig. 3.4.4-9(a) and (b), and successful message decoding shall be indicated in the reply report.



$$g_j^* = \begin{cases} 1; & j = 1, 2, \dots, 12, 14, 21 \\ 0; & \text{otherwise} \end{cases}$$

FIGURE 3.4.4-7
GENERATION OF CORRECTION ENABLE BIT

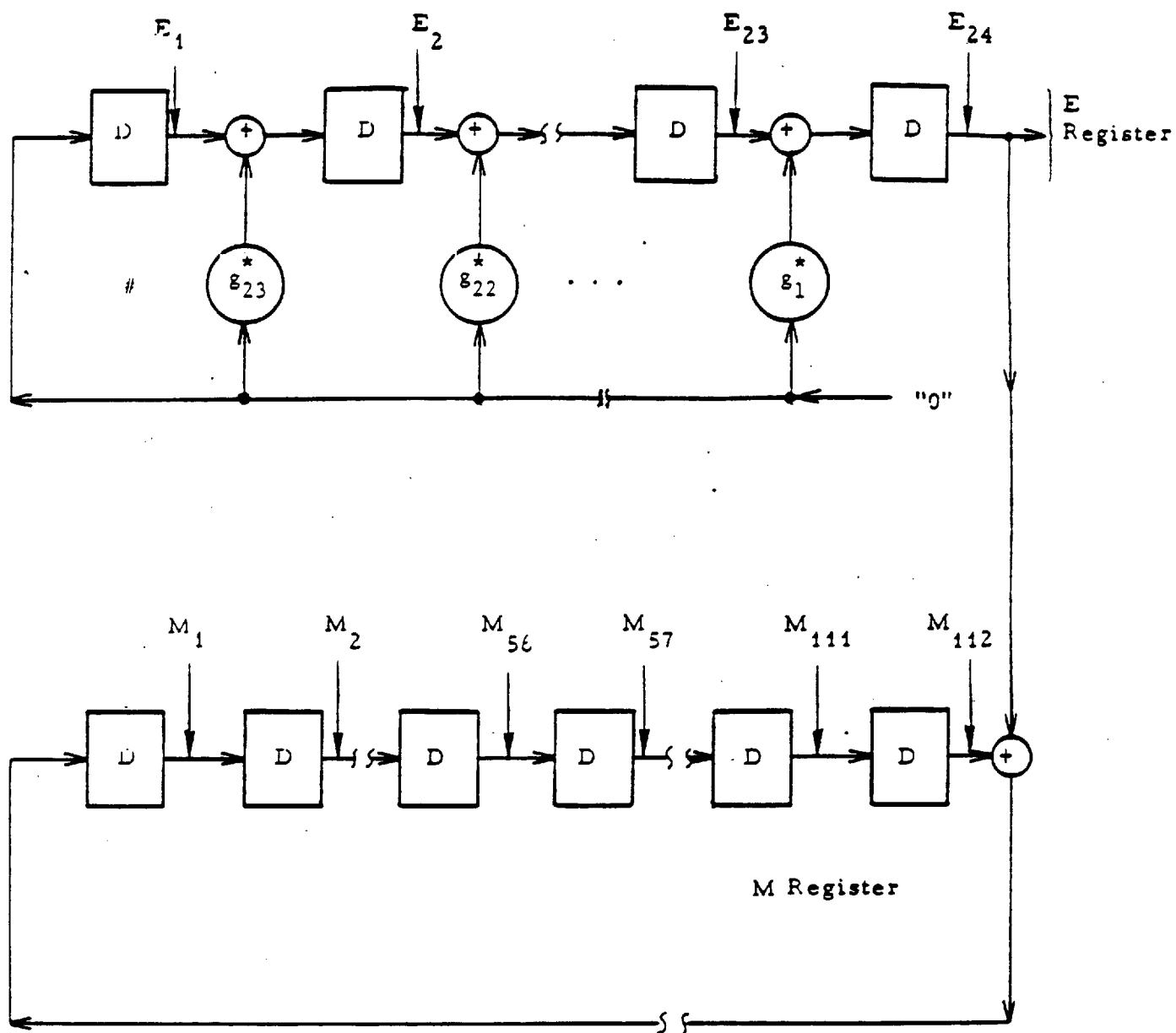
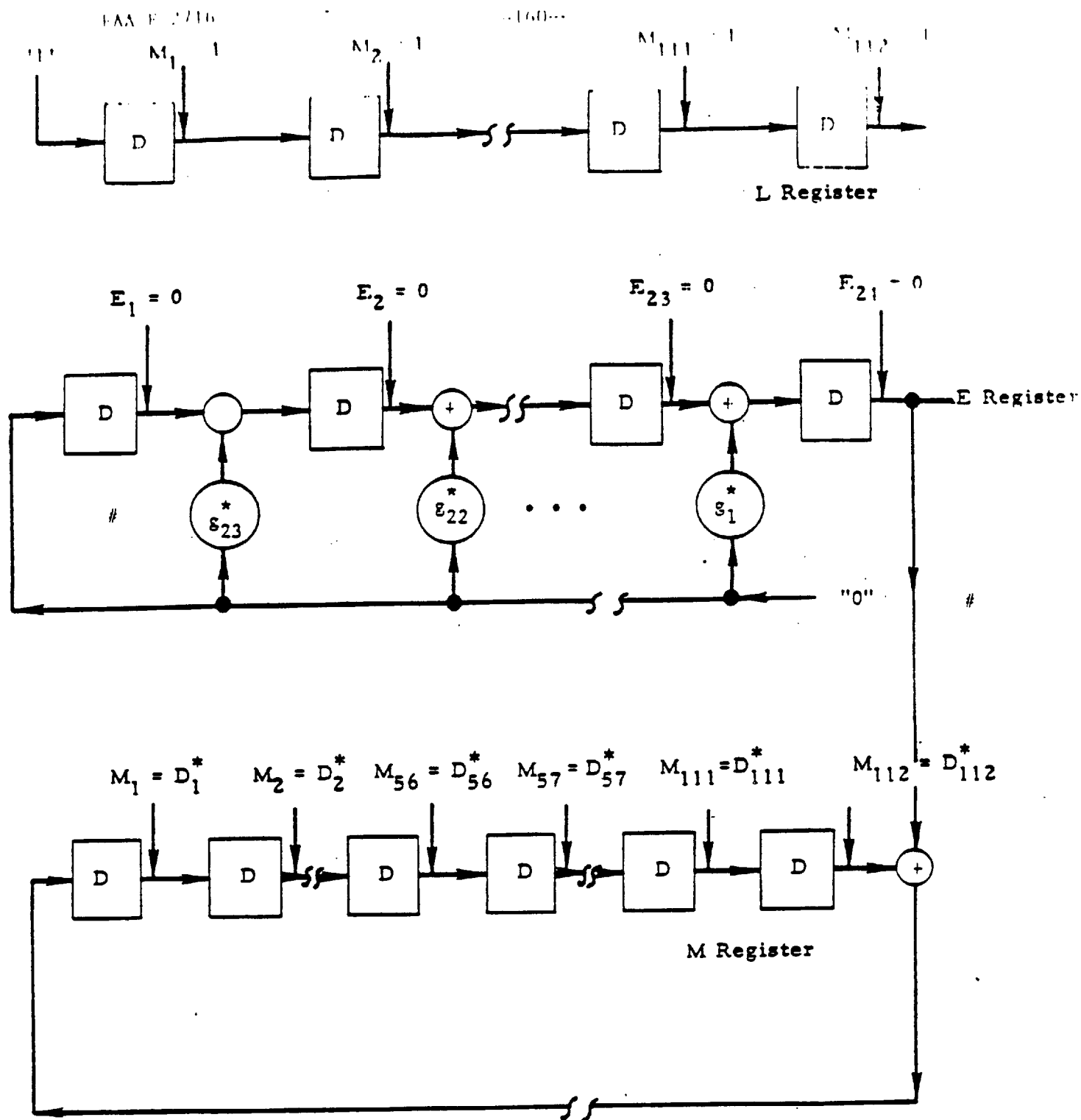


FIGURE 3.4.4-8
CORRECTION OF DECISION SEQUENCE



Note: D_i^* indicates corrected bit decision sequence.

FIGURE 3.4.4-9(a)
FINAL STATE OF ERROR CORRECTION
FUNCTION FOR $L = 1$ IF m WAS SET

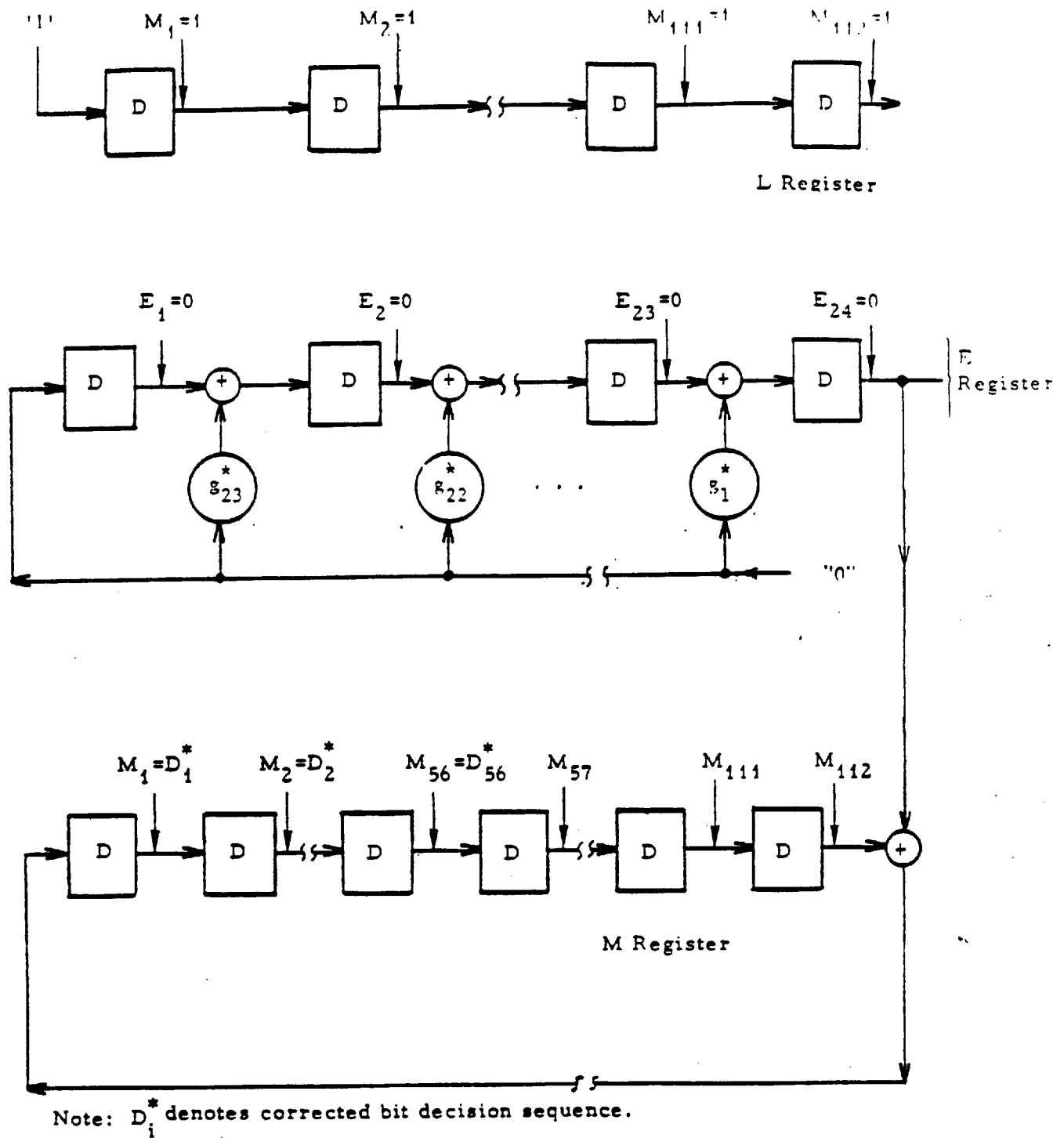


FIGURE 3.4.4-9(b)

FINAL STATE OF ERROR CORRECTION FUNCTION
FOR $L = 0$ IF m WAS SET

3.4.4.7 Antenna azimuth-range-timing unit (AARTU).- This unit shall provide timing and control signals to the sampling control logic, preamble detector, message bit processor, message decoder, while itself performing the functions of reading the antenna boresight azimuth encoder and the station clock at the instant of preamble detection. The AARTU requires the following inputs.

- (a) Station clock state (continuously available) (3.4.13.3).
- (b) Antenna boresight azimuth encoder outputs.
- (c) Roll-call reply processing information (content specified in 3.4.4.8.1):
- (d) All-Call reply processing information (content specified in fig. 3.4.2-1(d)):

The outputs of the AARTU are:

- (a) 16.000 MHz clock timing to the quantized sum video digitizer.
- (b) Control signals to the sampling control logic.
- (c) Preamble detector enable/inhibit signal.
- (d) 2.000 MHz timing signal to message bit processor.
- (e) Antenna azimuth register at time of preamble detection (14 bits).
- (f) Reply range estimate (range unit word, 3.4.13.3.2)

A block diagram of the AARTU and its interconnections to other subunits of the Mode S processing subsystem are shown in fig. 3.4.4-1.

3.4.4.7.1 Antenna azimuth register.- The antenna azimuth register shall accept inputs from the azimuth pulse generator (3.5.1.1) and provide a 14-bit antenna boresight azimuth word. Provision shall be included for manually entering a 14-bit word to correctly indicate the direction of true north independent of the orientation of the antenna pedestal.

3.4.4.7.1.1 Inputs.- The antenna azimuth register shall accept the following input signals:

- (1) Azimuth Change Pulses (ACP's) - 16,384 serial pulses per complete antenna revolution.
- (2) Azimuth Reference Pulse (ARP) - a pulse generated once each antenna revolution (between two ACP's) at a constant boresight azimuth.
- (3) North Correction Word - a 14-bit manually insertable word which specifies the direction of true north.

3.4.4.7.1.2 Outputs.- The outputs from the antenna azimuth register shall consist of the following signals:

- (1) Antenna Boresight Azimuth Word - a 14-bit parallel buffered output of the register indicating the antenna boresight azimuth relative to true north in azimuth units.
- (2) Azimuth Reference Mark Error - a signal indicating failure to count 16,384 ACP's between any two consecutive ARP's. This signal is to be transmitted to the performance monitoring function (3.4.10).

3.4.4.7.1.3 Antenna azimuth determination.- The state of the antenna azimuth register shall be sampled at the time of preamble declaration when a Mode S preamble is detected within the expected reply window for roll-call replies, and for any preamble detected during the All-Call listening period. The 14-bit antenna boresight azimuth word shall be included in the Mode S reply data blocks for All-Call and roll-call replies.

3.4.4.7.2 Range processing interval control.- There are two inputs required for every roll-call reply. These are the predicted earliest time of arrival of the reply (t_0 - determined from the surveillance file range estimate) and a reply window (w_p) during which the preamble detector shall be enabled to declare a valid Mode S reply. The reply window shall begin at the predicted earliest reply time and the remaining Mode S reply processing functions shall be activated only for preambles detected within that window. The Mode S roll-call listening interval shall be from t_0 to $(t_0 + w_p)$. If a valid preamble is not declared in that interval, a failure indication shall be generated and included in the reply report.

At the beginning of each ATCRBS/Mode S All-Call or Mode S-Only All-Call interval, two parameters are received representing time of transmission (t_1) and the length of the listening window (w_A). The listening window shall be from t_1 to $t_1 + w_A$. All valid preambles declared within that interval shall activate the reply processing functions for that reply.

3.4.4.7.3 Range and range delay determination.- Each valid preamble detection during the Mode S roll-call or All-Call listening periods shall result in strobing the station time clock state to produce the time-of-arrival estimate t_2 . This estimate shall be used to determine the range correction (Δr) for Mode S roll-call replies relative to the predicted earliest time-of-arrival or the range estimate (r) for All-Call replies using the P_3 or synch phase reversal transmission time, i.e. $\Delta r = c(t_2 - t_{\text{predicted}})$.

3.4.4.7.4 Mode and control signals.- The message bit processor shall be provided a message length indicator (56 or 112 bits) while the message decoder shall be provided both the message length indicator and expected address of the reply. A unique 24-bit address shall be provided for each roll-call reply.

An all-zero address shall be used during the ATCRBS/Mode S All-Call listening interval. When the Mode S -only All-Call interrogation is used the address for the All-Call listening interval shall equal the site address used in the interrogation.

During the ATCRBS/Mode S All-Call processing interval, detection of All-Call replies shall take priority over ATCRBS bracket detection. The monopulse channel A/D converter shall be time-shared between the Mode S and ATCRBS reply processors and the ATCRBS bracket detector shall be inhibited at each detection of a valid Mode S preamble within the range processing interval. The ATCRBS processor shall receive a Mode S preamble detection pulse to inhibit the bracket detector during the Mode S data block (3.4.5.4.4).

3.4.4.8 Information transfer to and from the Mode S processor. - Transmission control information shall be provided to the transmitter/modulation control unit and to the Mode S and ATCRBS reply processors in a time-ordered sequence such that each Mode S roll-call transmission and reply has a block of control information transferred from the channel management function. A single transmission control block shall be provided for each ATCRBS/Mode S or Mode S only All-Call interrogation.

For each Mode S scheduled roll-call target and each detected All-Call target, a target report shall be transmitted to the channel management and surveillance processing functions. The processor control block and target report contents and formats are specified in the following paragraphs.

3.4.4.8.1 Processor control blocks. - The channel management function shall provide a pair of receiver control blocks for each expected reply (or for an expected sequence of consecutive downlink ELMs for a given target) to the Mode S and/or ATCRBS reply processing subsystems. (See Fig. 3.4.2-1 (d)).

This space intentionally unused

Data block designator (Roll Call Short, Roll Call Long, All Call)	
Message bits (32 or 88)	
Failure indication	(3.4.4.8.2(b))
Antenna boresight azimuth	(3.4.4.7.1.3)
Monopulse estimate	(3.4.4.2.5)
Range correction or all call range (range unit word, 3.4.13.3.2)	
Time-of-day of reply	(3.4.13.2.2)

Figure 3.4.4-10 Mode S Reply Data Block Content

3.4.4.8.2 Target reports. - The Mode S processing subsystem shall provide a target report for each reply processed successfully during a scan. These target reports shall contain the following information (see fig. 3.4.4-10).

- (a) Message bits (32 or 88 bits)
- (b) Failure indication (resulting if:)
 - No preamble detected in range window,
 - Error correction not possible,
 - No monopulse azimuth estimate
- (c) Antenna boresight azimuth (3.4.4.7.1.3)
- (d) Monopulse estimate (3.4.4.2.5)
- (e) Target range, All-Call replies (range unit word, 3.4.13.3.2)
- (f) Range correction, roll-call replies, D_2 (range unit word, 3.4.13.3.2)
- (g) Time of day for this reply (3.4.13.2.2)

Only All-Call replies shall have their reply data block transferred to the surveillance processing function during a Mode S All-Call processing interval. Each reply received shall have a complete reply data block transmitted no matter what failure condition has been indicated. The fields of the block for which no information is available shall be set to zero.

3.4.4.8.3 Altitude report transformation. - In Mode S replies containing an altitude report the 12 altitude code pulse positions and the M bit position appearing in the reply shall be rearranged using the transformation described in paragraph 3.4.5.3.3.1 (with the M bit replacing the X bit).

This space intentionally unused.

3.4.5 ATCRBS reply and reply-to-reply correlation processing.- The ATCRBS processing subsystem shall process the multichannel receiver video output signals to detect ATCRBS targets, estimate target range and azimuth, and decode altitude reports and discrete (4096) mode A and mode 2 codes. The inputs to the ATCRBS processing subsystem from the multichannel receiver are:

- (a) Quantized video signals (QIA, QEPS, QENS, QSLSA),
- (b) Monopulse video (ϕ).

In addition, the following inputs are also required by the ATCRBS processing subsystem:

- (c) Station time clock (3.4.13.3).
- (d) Antenna azimuth register (3.4.4.7.1).
- (e) Single sweep processing information from the processor control block (Content specified in fig. 3.4.2-1(d)):
- (f) Mode S preamble detection trigger pulse.
- (g) Time-of-day clock, continuously available (3.4.13.2.2).

The output of the ATCRBS processing subsystem consists of target reports, one per scan per ATCRBS target. Each target report shall contain the information specified in 3.4.5.7.

3.4.5.1 Major subunits of the ATCRBS processor.- A functional block diagram of the ATCRBS processing subsystem is shown in fig. 3.4.5-1.

The major subunits of the processor are:

- (a) Video digitizer.
- (b) Reply processor.
- (c) Antenna azimuth range timing unit (AARTU).
- (d) Reply correlator.

The detailed design requirements of each of these subunits are specified in the following paragraphs.

3.4.5.2 Video digitizer.- The function of the video digitizer is to provide digital data in appropriate format for reply processing. A functional block diagram of the video digitizer is shown in fig. 3.4.5-2.

3.4.5.2.1 Video pulse quantizer/digitizer.- The video pulse quantizer/digitizer (VPQ) circuit shall operate on the three quantized video signals derived from $\log |I|$, namely, the QIA, QEPS, and QENS signals to produce a clocked binary data stream which represents detected pulses by leading edge samples (a single '1' representing a single pulse at the location in time of the estimated pulse leading edge).

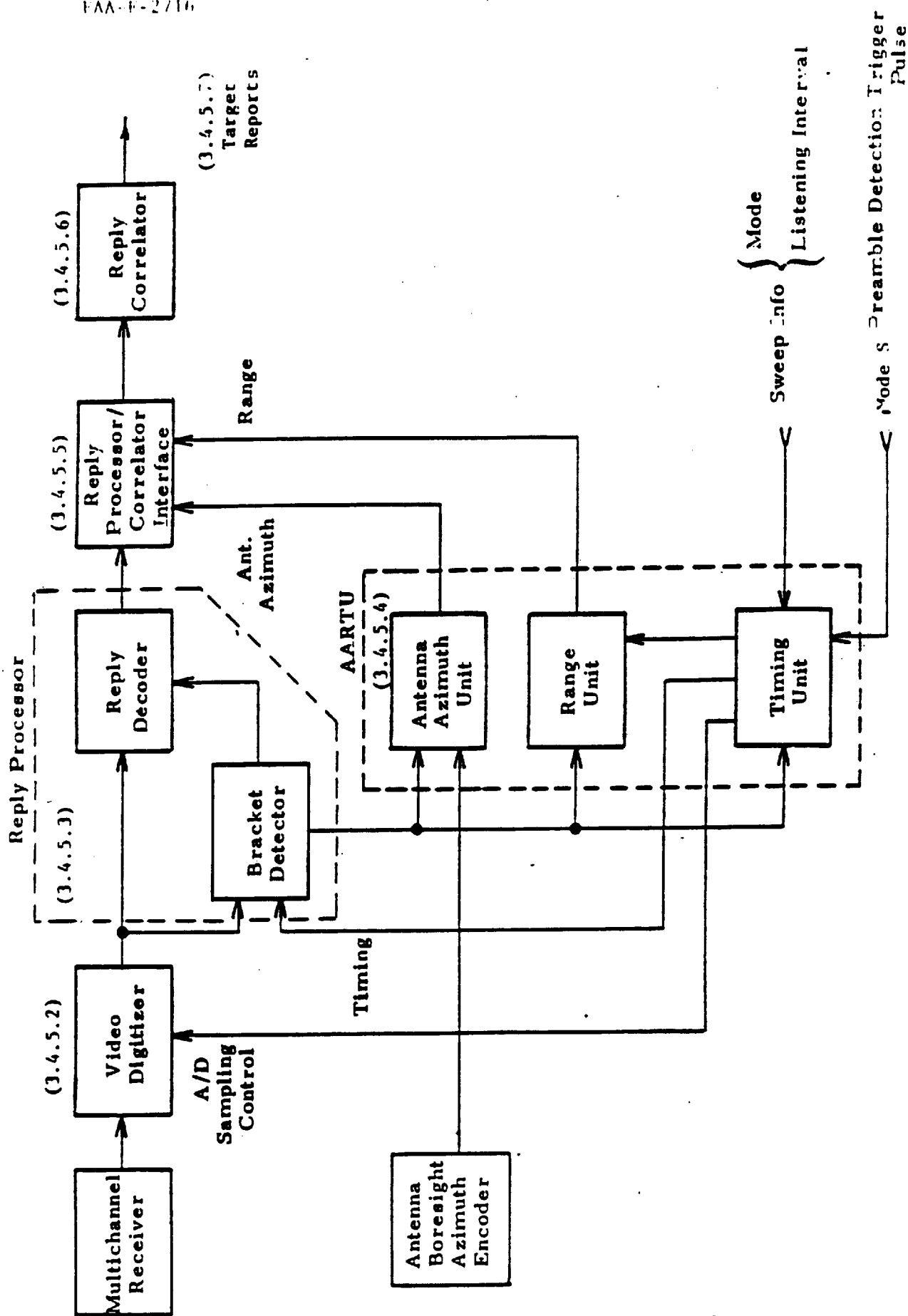


FIGURE 3.4.5-1
ATACRES PROCESSOR FUNCTION BLOCK DIAGRAM

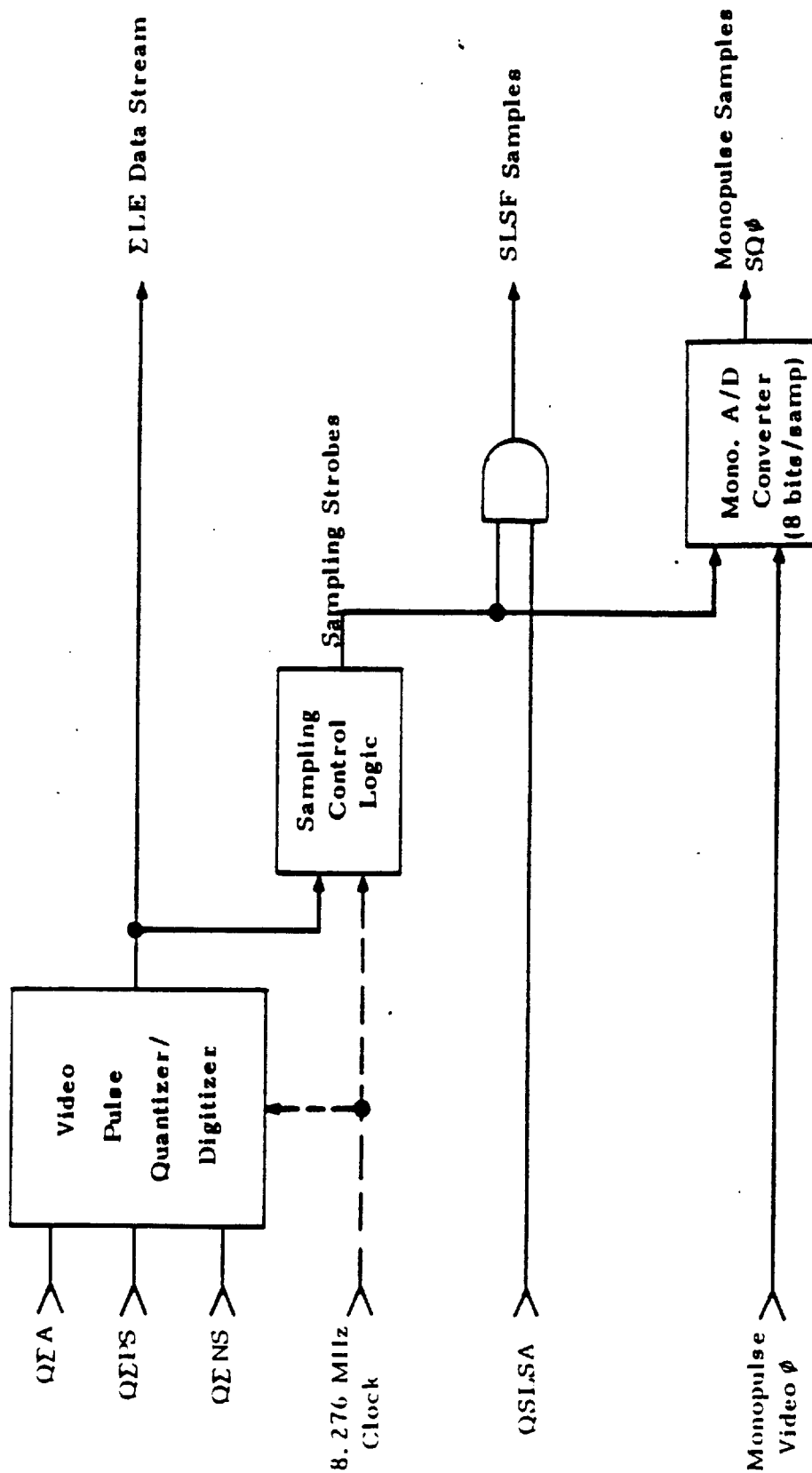


FIGURE 3.4.5-2 ATCRBS VIDEO DIGITIZER

The output data stream of the ATCRBS VPQ, denoted ELE, shall be clocked at 8.276 MHz and shall drive the ATCRBS bracket detector and reply decoder.

3.4.5.2.1.1 Leading edge declaration.- The VPQ circuit shall declare a pulse "leading edge" at time t_1 , signified by a transition of its next output binary digit (from its leading edge output) from the "0" state to the "1" state, whenever all of the following conditions are satisfied simultaneously:

- (a) $QEA(t_1 + d) = 1$
- (b) $QEPS(t_1) = 1$
- (c) $QEPS(t_1 + d) = 0$

The time d shall be one 8.276 MHz clock period.

3.4.5.2.1.2 Trailing edge declaration.- The VPQ shall declare a trailing edge at time t_2 , signified by a transition of its next output binary digit (from its trailing edge output) from the "0" state to the "1" state if a previous leading edge had been declared and no subsequent trailing edge had been declared, and:

$$QEA(t_2) = 0$$

The VPQ shall declare a potential trailing edge at time t_2 if a previous leading edge had been declared and no subsequent trailing edge had been declared and the following conditions are satisfied simultaneously:

- (a) $QENS(t_2 - d) = 0$
- (b) $QENS(t_2) = 1$

The parameter d shall be one 8.276 MHz clock period.

A potential trailing edge at time t_2 shall be declared an actual trailing edge if:

- (a) $QEA(t_2 + d) = 0$, or
- (b) $QENS(t_2 + d) = 1$, and $QEA(t_2 + 2d) = 0$, or
- (c) $QENS(t_2 + d) = 1$, and $QEPS(t_2 + 2d) = 1$, or
- (d) $QENS(t_2 + d) = 1$, and $QINS(t_2 + 2d) = 1$.

3.4.5.2.1.3 Pseudo-leading edge declaration and short pulse rejection.- The ATCRBS VPQ circuit shall reject short pulses and make pseudo-leading edge estimates on the basis of apparent pulse width determined from the number of sample intervals between a leading edge and a trailing edge, or between two successive leading edges. The VPQ output shall be a binary data stream clocked at the sample frequency of 8.276 MHz and denoted by ELE. Pulses shall be represented in the ELE data stream by a '1' corresponding to a directly declared leading edge or a pseudo-leading edge inserted according to the rules given

below. When a leading edge declaration is followed by a trailing edge declaration, PW is used to denote this pulsewidth in terms of sample intervals. LW is used to denote the spacing between two successively declared leading edges in terms of sample intervals.

- (a) If $PW = 1$ then the leading edge shall not be represented in the ELE data stream, but all other directly declared leading edges shall be represented in the ELE data stream.
- (b) If $PW > 6$ then a pseudo-leading edge shall be declared at the sample time four sample intervals prior to the declared trailing edge.
- (c) If $PW = 10$ then an additional pseudo-leading edge in addition to that in (b) shall be declared at the third sample interval following the leading edge. This pseudo-leading edge shall have a zero monopulse value (see 3.4.5.2.4.).
- (d) If $PW > 10$ then additional pseudo-leading edges shall be declared every fourth sample interval following the leading edge but prior to the pseudo-leading edge inserted in (b). These pseudo-leading edges shall have a zero monopulse value (3.4.5.2.4.).
- (e) If $LW > 5$ then additional pseudo-leading edges shall be declared every fourth sample interval following the first leading edge but prior to the second leading edge. These pseudo-leading edges shall have a zero monopulse value.

3.4.5.2.2 Sampling control logic.- For each pulse of acceptable width represented by a directly declared leading edge sample in the ELE data stream, a sampling control pulse shall be generated to sample the monopulse video δ_L ns after its leading edge time of occurrence as determined by the VPQ logic. That is, after allowing for VPQ processing delay, the monopulse video shall be sampled δ_L ns after the point of the Log |E| video waveform corresponding to the '1' in the ELE data stream which represents the leading edge estimate of the pulse. For each pulse represented by a pseudo-leading edge in the ELE data stream, a sampling control pulse shall be generated to sample the monopulse video δ_T ns after the pseudo-leading edge estimate as determined by the VPQ logic.

The parameters δ_L and δ_T shall be independently adjustable over a range of 100 to 400 ns in steps no greater than 20 ns with nominal value of:

$$\begin{aligned}\delta_L &= 240 \pm 10 \text{ ns} \\ \delta_T &= 300 \pm 10 \text{ ns}\end{aligned}$$

It is intended that the sampling control logic provide samples of the monopulse video waveform that fall within the 0.2 μ s sampling window described in 3.4.3.2.3.

3.4.5.2.3 Quantized SLS video digitizer.- The two level video waveform QSLSA provided by the log video comparator (3.4.3.4.5.3) shall be sampled once per pulse leading edge (and pseudo-leading edge) indicated in the LLE data stream with the time of each sample governed by the sampling control logic (3.4.5.2.2). The resulting sample values shall be binary, with a '0' denoting the QSLSA signal in the '0' state (a sidelobe pulse), and a '1' denoting the complementary event.

The output of the quantized SLS video digitizer will be denoted by SLSF (sidelobe suppression flag).

3.4.5.2.4 Monopulse digitizer.- The monopulse video signal shall be sampled once per pulse leading edge indicated in the LLE data stream with the time of each sample governed by the sampling control logic (3.4.5.2.2) except for spacings between two leading edges of two sample intervals. In the case of two edges separated by two sample intervals, a monopulse sample for the second pulse is taken but the sample is not taken for the first pulse and its 8-bit monopulse sample value is set to zero to signify this.

In addition, the monopulse video signal is sampled once for each pseudo-leading edge defined by rule 3.4.5.2.1.3(b). Other pseudo-leading edges shall have their monopulse sample values set to zero.

The output of the monopulse digitizer will be denoted as SQ ϕ .

3.4.5.3 ATCRBS reply processor.- The function of the reply processor is to declare bracket pulse pairs, eliminate phantom brackets due to garbling replies, derive a monopulse estimate for each reply declared using clear pulses, estimate clear code pulses, and generate a confidence indication which defines which information pulses are clear and can be used in the correlation operations which follow. The SPI and X pulses shall also be detected and reported if present.

The inputs to the reply processor shall be digital signals from the video digitizer unit, namely,

- (a) LLE, continuous clocked data stream.
- (b) SLSF, one bit sample per pulse represented in the LLE data stream (by a '1' denoting its leading edge or pseudo-leading edge).
- (c) Monopulse samples SQ ϕ , one 8-bit sample per pulse represented in the LLE data stream (by a '1' denoting its leading edge or pseudo-leading edge).

No differentiation shall be made between pseudo-leading and leading edges in the reply processor.

The basic functions of the reply processor are broken down into the following set:

- (a) Bracket detection.
- (b) Garble/interleave sensing and phantom elimination.
- (c) Monopulse average initialization.
- (d) Monopulse correlation.
- (e) Pulse processing.
- (f) Monopulse averaging.

A functional block diagram of the reply processor is shown in fig. 3.4.5-3.

The output of the reply processor consists of reply reports, one report per detected mainbeam reply, containing at least the following information:

- (a) Range estimate (range unit word, 3.4.13.3.2)
- (b) Monopulse average (3.4.5.3.2.6)
- (c) Lower 8 bits of antenna boresight azimuth at bracket detection (3.4.4.7.1)
- (d) ATCRBS Code pulse estimates, including X, SPI
- (e) ATCRBS Code confidence level indication, including X, SPI
- (f) ATCRBS Mode indicator

Note: Pulse spacing tolerances shall be selectable under parameter control as ± 1 or ± 2 sample periods (1.45/12 microseconds). Processing values are shown for the ± 1 sample period case with values for the ± 2 sample period case immediately thereafter in square brackets, e. g., $n * 12 \pm 2$ [± 4] samples.

3.4.5.3.1 Reply (bracket pair) detection. - An ATCRBS reply shall be recognized on the basis of the two framing pulses, F_1 and F_2 , which are included in every reply. Declaration of a bracket pair shall be accomplished using the following criterion:

A bracket pair shall be declared whenever two pulse leading edges in the Σ LE data stream are detected with a separation of 168 ± 1 (± 2) sample intervals but sidelobe replies shall not be reported. A sidelobe reply is defined as one having both bracket pulses labeled as non-mainbeam (SLSF not equal to 1).

The time of arrival of the bracket pair is taken as the time of occurrence of the F_1 pulse leading edge sample in the Σ LE data stream. The spacing of the C_2 code pulse and the SPI pulse of a reply is exactly the same as that of a bracket pair, and may thus result in false bracket when both of these pulses are present in a reply. Such a false bracket will be referred to as an SPI phantom according to the rules in 3.4.5.3.2.5 and shall not be declared as a bracket pair.

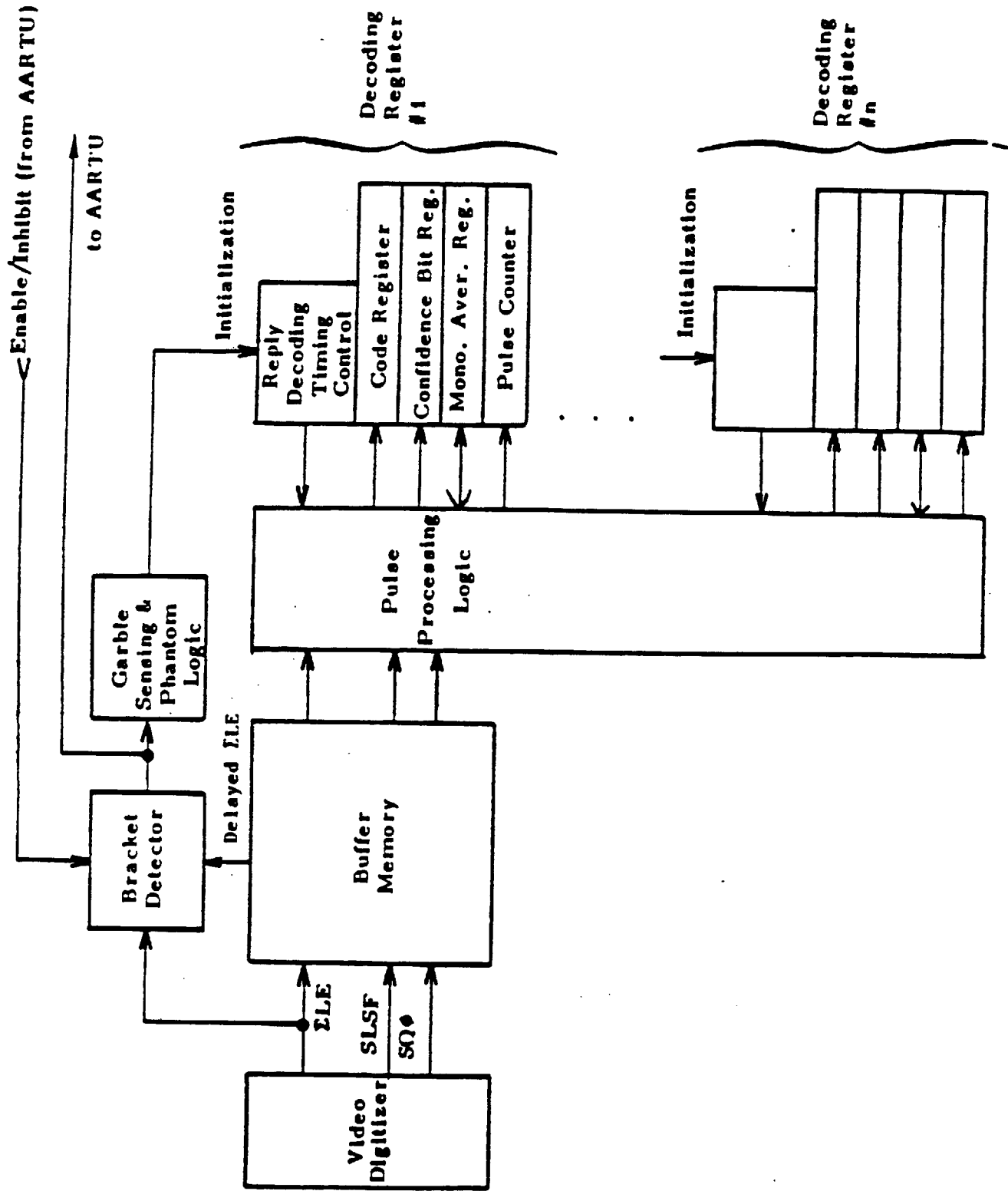


FIGURE 3.4.5-3

ATCRDS REPLY PROCESS FUNCTIONAL BLOCK DIAGRAM

3.4.5.3.1.1 Multiple reply sensing. Two replies are referred to as interfering whenever the leading edge samples of their F_1 pulses are separated by no more than 170 [172] sample intervals in the ΣLE data stream. Two replies are referred to as closely spaced if the leading edge samples of their F_1 pulses are separated by not less than 171 [173] sample intervals but no more than 338 [340] sample intervals in the ΣLE data stream. Two interfering replies are referred to as garbling if the F_1 pulse leading edge sample of the later reply occurs in one of the fourteen intervals $n * 12 \pm 2$ [± 4] samples ($n = 1, 2, \dots, 14$) later than the F_1 pulse leading edge sample of the earlier reply. (Valid code pulse positions of each of two garbling replies overlap, resulting in ambiguity in associating pulses with either of the two replies.) Two replies are said to be interleaved if their F_1 pulse leading edge samples are separated by from 3 [5] to 165 [163] samples of the ΣLE data stream, and if they are not garbling.

A phantom bracket is defined as a declared bracket whose F_1 pulse is a valid code pulse or framing pulse of one reply and whose F_2 pulse is a valid code or framing pulse of another reply. Figure 3.4.5-4 shows an example of two replies which are separated in time so that the A_1 pulse of the earlier reply and the B_4 pulse of the second reply are separated by the standard bracket pulse pair spacing. The ATCRBS processor shall include logic circuitry to eliminate phantom brackets resulting from two interfering or closely spaced replies.

Both bracket pairs of two interfering replies shall be declared only when the F_1 pulse leading edge sample occurs 3 [5] or more samples later than that of the earlier reply in the ΣLE data stream. A reply shall be declared a garbled reply at the time of bracket detection if its F_1 pulse leading edge sample falls in one of the intervals $n * 12 \pm 2$ [± 4] ($n = 1, 2, \dots, 14$) after the F_1 pulse leading edge sample of a previously declared bracket pair.

A bracket pair shall be declared a potential phantom bracket if, and only if, the leading edge sample of its F_1 pulse occurs in one of the fourteen intervals $n * 12 \pm 1$ [± 2] ($n = 1, 2, \dots, 14$) after the F_1 pulse leading edge sample of a previously declared bracket pair. A bracket pair shall be declared a phantom and eliminated if, and only if,

- (a) It was declared a potential phantom at the time of bracket detection and,
- (b) A bracket pair is declared whose F_1 pulse leading edge sample occurs in one of the intervals $n * 12 \pm 2$ [± 4] ($n = 1, 2, \dots, 14$) following the F_1 leading edge of the potential phantom bracket.

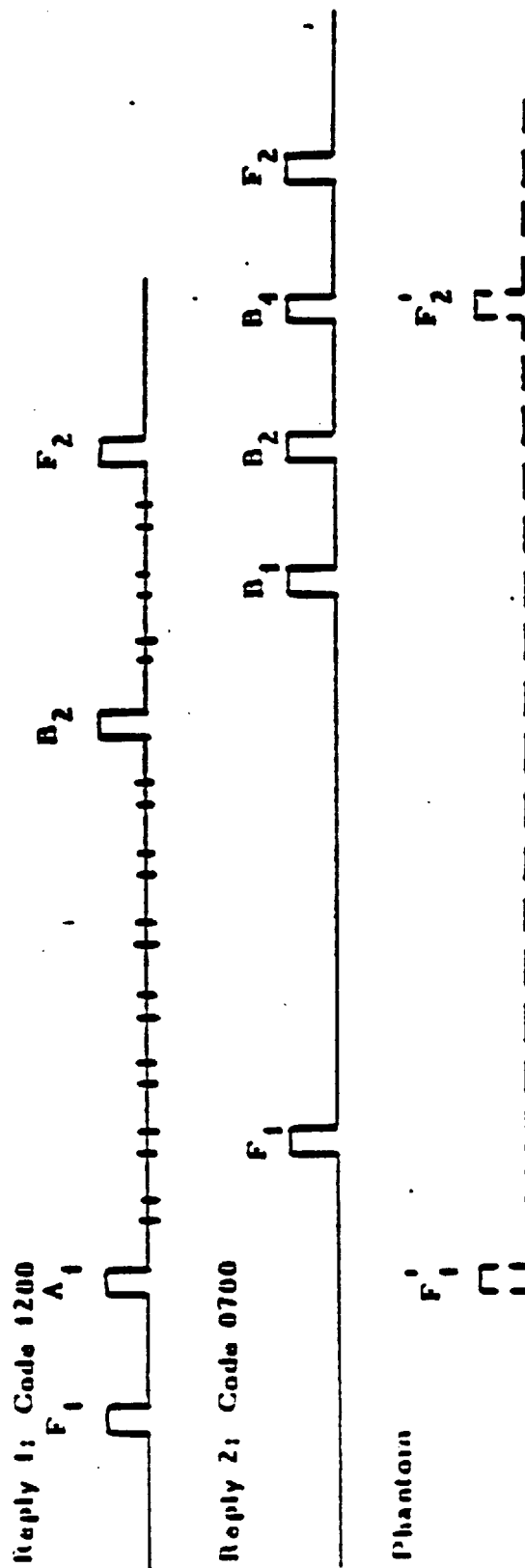


FIGURE 3.4.5-4
EXAMPLE OF PHANTOM BRACKET PULSE PAIR

3.4.5.3.2 Reply decoding.- The decoding of a reply shall commence after its bracket pair has been detected. Valid code pulse leading edge locations for reply decoding are defined as occurring in the intervals $n * 12 \pm 1 [\pm 2]$ samples ($n = 1, 2, \dots, 13$) after the leading edge sample of the F_1 pulse. Valid SPI pulse leading edge locations are taken to be in the interval $204 \pm 1 [\pm 2]$ samples after the leading edge sample of the F_1 pulse.

A valid code pulse position of one reply shall be considered to be potentially garbled if it is overlapped by a valid code pulse position of any other reply being decoded. Clear pulse positions shall be processed according to the rules given in 3.4.5.3.3.1, while potentially garbled pulse positions shall be processed according to the rules given in 3.4.5.3.3.2.

Following bracket detection, reply decoding shall begin by initializing the monopulse average for the reply as described in 3.4.5.3.2.3. Code pulses shall be associated with a reply on the basis of their leading edge locations for the reply being decoded, and also on the basis of the arithmetic difference between their monopulse sample values and the current value of the monopulse average for the reply being decoded (the 8-bit monopulse sample and average values being considered to be integer valued, ranging from 0 to 255).

When the magnitude of the arithmetic difference between the monopulse sample of a pulse and the monopulse average of a reply being decoded is less than a specified value k , the monopulse sample is said to correlate with the reply being decoded. The correlation window parameter k shall be manually adjustable and of value $20(0-63,1)$. Monopulse samples with the value zero shall be considered to not correlate with any monopulse value and monopulse values of zero shall be considered to not correlate with any monopulse sample value.

3.4.5.3.2.1 Multiple reply processing capability.- The reply decoder shall be capable of decoding up to four different replies simultaneously (i.e., where the F_1 pulse of the fourth (last) reply precedes the SPI pulse position of the first (earliest reply)). An example of a decodable arrangement of four interfering replies is a garbling pair of replies (complete pulse overlaps) interleaved by another garbling pair of replies with complete pulse overlaps.

3.4.5.3.2.2 Buffer memory.- Reply decoding commences with the declaration of a bracket pair, which requires processing the last pulse in the reply (F_2) before the reply is declared. This necessitates storing pulse information temporarily in a buffer memory until the F_2 pulse of a reply is detected and a bracket pair is declared. The pulse information shall then be made accessible to the reply processor at an appropriate time following bracket declaration. The buffer memory shall store, for each detected pulse, sufficient information to provide the reply decoder with the following:

- (a) ELE time of occurrence (in terms of sample numbers).
- (b) SLSF sample (1 bit per pulse).
- (c) SQ ϕ monopulse sample (8 bits per pulse).

3.4.5.3.2.3 Monopulse average initialization.- In the case of a reply which is not known to be garbled at the time of bracket declaration, the monopulse average for the reply shall be initialized with the monopulse sample value corresponding to the F_1 pulse if:

SLSF = 1 for the F_1 pulse.

If the reply is known to be garbled at the time of bracket declaration, or if the condition above is not satisfied, the monopulse average for the reply shall be initialized with the monopulse sample value corresponding to the F_2 pulse if:

SLSF = 1 for the F_2 pulse.

If the initialization conditions for neither the F_1 pulse nor the F_2 pulse are satisfied at the time of bracket declaration, the reply shall be discarded. If after initializing the monopulse average with data corresponding to the F_2 pulse, the F_2 pulse is found to be in a garbling position, the reply shall be discarded.

3.4.5.3.2.4 Monopulse average updating.- The monopulse average for a particular reply, which is in the process of being decoded, shall be updated by the monopulse sample of a clear pulse by arithmetically adding the monopulse sample of the clear pulse to the monopulse average and dividing the sum by two. This updated monopulse average shall replace the original monopulse average for subsequent monopulse correlation tests until updated again.

The rules for determining which monopulse samples shall be used to update a monopulse average are given in 3.4.5.3.3.1 and 3.4.5.3.3.2. All pulses present in a reply, except the framing pulse that was used to initialize the monopulse average, shall be tested according to these rules to determine whether or not to update the monopulse average.

The SPI pulse shall not be used to update the monopulse average of a reply.

3.4.5.3.2.5 SPI phantoms.- A bracket declaration for which the F_2 pulse is in a valid SPI pulse leading edge location of another reply and the monopulse sample correlates with the other reply shall be called an SPI phantom.

3.4.5.3.2.6 Monopulse estimate.- The final monopulse estimate for a decoded reply shall be the value of the monopulse average when the decoding of F_2 is completed. Unless at least two monopulse samples have been used in forming the average, no monopulse estimate shall be output and this failure mode shall be indicated to the reply correlation function by setting the 8-bit monopulse estimate to all zeros.

3.4.5.3.2.7 Special military replies.- Certain military transponders indicate EMERGENCY and IDENT conditions with a special reply format. These special military reply formats are defined in the following paragraphs. Related processing may be performed in either the reply processor hardware or in the reply/reply correlation software.

3.4.5.3.2.7.1 Military IDENT.- In lieu of the single SPI pulse following the second framing pulse (F_2) by 4.35 ± 0.1 μ s, the complete code train is repeated, with the first framing pulse (F_1) of the second code train occupying the SPI pulse position of the first code train. These latter replies shall be recognized as military replies and discarded.

3.4.5.3.2.7.2 Military EMERGENCY.- In lieu of the single code 7700 reply, four reply pulse trains are transmitted, with the first framing pulse (F_1) of each reply train occupying the SPI pulse position of the preceding pulse train. The code pulses of the first pulse train will be set to correspond to the code 7700, and the succeeding reply trains all discarded.

3.4.5.3.2.8 Reply processor overload indication.- The reply processor shall indicate loss of data during a sweep due to replies that are lost because of total decoding register occupancy or reply processor/correlator interface overflow. This loss of data shall be indicated by setting the overload indicator bit to '1' in the initial message sent to the reply-to-reply correlator for the next sweep (3.4.5.5).

3.4.5.3.3 Pulse processing.- After the arrival of a reply is detected (on the basis of its bracket pulses), valid code pulse leading edge positions for the reply are determined, and the monopulse average for the reply is initialized (whether the reply was garbled or not). The pulse data emerging from the buffer memory (3.4.5.3.2.2) shall next be processed according to the rules given in the following paragraphs. The rules for decoding the thirteen code pulse positions between the bracket pulses are given in the following two sections, as well as the rule for updating the monopulse average for the reply. Rules are also given for the generation of confidence bits (one per code pulse position) for these thirteen code pulse positions to indicate high or low confidence decoding decisions. The SPI pulse position is decoded using the same rules as for code pulse positions.

Pulse processing shall result in fourteen code pulse estimates (including 12 information pulses, the X pulse, and the SPI pulse), fourteen confidence bits, and a monopulse average for the reply.

3.4.5.3.3.1 Clear pulse processing.- The valid code pulse positions of a reply being decoded are defined by the leading edge sample intervals $n * 12 + 1$ [± 2] ($n = 1, 2, \dots, 13$) after the F_1 pulse leading edge sample of the reply. A valid pulse position is said to be clear if none of its three [five] valid

leading edge sample positions is also a valid leading edge sample position of a code pulse or bracket pulse of some other reply being decoded. The valid range of SPI pulse leading edge sample positions is taken to be 204 ± 1 [± 2] samples after the leading edge sample of F_1 .

In the case of clear code pulse positions, a '1' shall be decoded if a leading edge of a mainbeam pulse (SLSF = 1) occurs in one of the three [five] valid leading edge positions, and a declared '1' shall be declared a high confidence decision (i.e., with the confidence bit corresponding to the bit position set to '1') if the monopulse sample of the pulse correlates (3.4.5.3.2) with the current value of the monopulse average for the reply. A '0' shall be decoded with high confidence only if no leading edge is detected in the three [five] valid leading edge sample positions for the code pulse as well as in the sample position just prior (in time) to the three [five] valid leading edge sample positions.

A monopulse sample of a clear code pulse decoded as a '1' or a framing pulse shall be used to update the monopulse average of the reply if it correlates with the current value of the monopulse average.

The pulse processing rules for clear pulses are given more precisely and completely in terms of a Boolean logical function which is tabulated in Table 3.4.5-1. The definitions of the Boolean variables to be used in the logical function are as follows:

- (a) $P_1 = 1$ Denotes the occurrence of a leading edge in the range $1 * 12 \pm 1$ [± 2] samples after the F_1 leading edge sample of the reply labeled P , being decoded.
- (b) $P_1^2 = 1$ Denotes the occurrence of two [two or three] leading edges in the valid P_1 leading edge sample positions.
- (c) $J_1 = 1$ Denotes a pulse leading edge $1 * 12 - 2$ [-3] samples after the F_1 leading edge sample of the P - reply.
- (d) $C_{p1} = 1$ Denotes that the monopulse sample of the pulse in the P_1 position correlates with the P - reply monopulse average, and the pulse is a mainbeam pulse (SLSF = 1).

The above variables take on the value '0' if the conditions above are not satisfied.

3.4.5.3.3.2 Overlapped pulse processing. - A valid code pulse position of a reply being decoded is said to be overlapped if one or more of its three valid leading edge sample positions is also a valid leading edge position of a code pulse or bracket pulse of some other reply being decoded. The rules for

TABLE 3.4.5-1 CLEAR PULSE PROCESSING DECISION RULES.

<u>Event</u>	<u>Use P_1 monopulse sample to update average (if term is '1')</u>	<u>P_1 pulse decode decision = '1' (if term is '1')</u>	<u>P_1 pulse confidence bit = '1' (High Confid.) (if term is '1')</u>
$\bar{P}_1 \cdot \bar{J}_1$	0	0	1
$\bar{P}_1 \cdot J_1$	0	0	0
P_1	C_{P1}	1 (SLSF) (see Note 5)	C_{P1}
P_1^2	C_{P1}	1	C_{P1} (see Note 3)

Notes:

- (1) The bar notation ($\bar{*}$) denotes the logical complement.
- (2) The dot notation ($A \cdot B$) denotes a logical AND function.
- (3) For the P^2 event, both [all] of the pulses shall be used in the correlation test C_{P1} , and if either one [any one] passes the test, it shall be associated with the P-reply (and used to update the monopulse average).
- (4) The SPI pulse decoding shall also use the above rules for both the pulse decode decision and confidence bit.
- (5) The variable SLSF is defined in 3.4.5.2.3.

decoding pulse positions which are overlapped are given in Table 3.4.5-2. This table also applies to the use of the monopulse sample of a framing pulse which is also in the valid decode region of a pulse or bracket pulse of some other reply being decoded. In addition to the Boolean variables defined in 3.4.5.3.3.1, the following definitions are used in Table 3.4.5-2.

- (a) $G_1 = 1$ Denotes the occurrence of a leading edge in one of the valid P_1 leading edge sample positions which is also in a valid code pulse or bracket pulse leading edge sample position of some other reply or replies (denoted Q) being decoded.
- (b) $H_1 = 1$ Denotes the occurrence of a leading edge in one of the valid P_1 leading edge sample positions but which is not in a valid code pulse leading edge sample position of some other reply being decoded.
- (c) $C_0 = 1$ Denotes that the monopulse sample corresponding to the pulse in one of the G_1 positions correlates with the monopulse average of some other reply being decoded.
- (d) $G_1^2 = 1$ Denotes the occurrence of two [two or three] leading edges in the G_1 sample position.
- (e) $H_1^2 = 1$ Denotes the occurrence of two [two or three] leading edges in the H_1 sample position.

3.4.5.3.3.3 Code pulse transformation.— The rearrangement of the order of the code bits from the order in which they are decoded will be referred to as a transformation. The following transformation shall be used by the reply processor to rearrange code bits for Mode A, C, and 2 replies.

Decoding Order: $C_1 A_1 C_2 A_2 C_4 A_4 X B_1 D_1 B_2 D_2 B_4 D_4$ (SPI)

Output Order: $A_4 A_2 A_1 B_4 B_2 B_1 C_4 C_2 C_1 D_4 D_2 D_1 X$ (SPI)

The reply processor shall rearrange the order of the confidence bits using this same transformation for Mode A and Mode C confidence bit sequences.

3.4.5.4 Antenna azimuth-range-timing unit (AARTU).— This unit performs a function analogous to that of the AARTU of the Mode S processor, described in 3.4.4.7, and, to the extent practicable, the functions of both AARTU's may be combined in a single unit.

The inputs to the AARTU are:

- (a) Station clock (3.4.13.3).
- (b) Antenna boresight azimuth encoder (continuously available, 14 bits)
- (c) ATCRBS reply processing information (content specified in fig. 3.4.2.1(d)).
- (d) Mode S preamble detection trigger pulse.

TABLE 3.4.5-2 OVERLAPPED PULSE PROCESSING DECISION RULES.

<u>Event</u>	<u>Use P_1 monopulse sample to update average (if term = '1')</u>	<u>P_1 pulse decode decision =1' (if term = '1')</u>	<u>P_1 pulse confidence bit =1' (High Confid.) (if term = '1')</u>
$\bar{G}_1 \cdot \bar{H}_1 \cdot \bar{J}_1$	0	0	1
$\bar{G}_1 \cdot \bar{H}_1 \cdot J_1$	0	0	0
$\bar{G}_1 \cdot H_1$	C_{P1}	1 (SLSF)	C_{P1}
$G_1 \cdot \bar{H}_1$	$C_{P1} \cdot \bar{C}_Q$	$(C_{P1} + \bar{C}_{P1} \cdot \bar{C}_Q) \cdot \text{SLSF}$	$C_{P1} \cdot \bar{C}_Q$
$G_1 \cdot H_1$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$
G_1^2	$C_{P1} \cdot \bar{C}_Q$ (see Note 1)	1	$C_{P1} \cdot \bar{C}_Q$ (see Note 1)
$G_1 \cdot H_1^2$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$
$G_1^2 \cdot H_1$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$	$\begin{cases} 1 \\ 1 \end{cases}$	$\begin{cases} C_{P1} \cdot \bar{C}_Q \text{ for } G_1 \text{ (see Note 1)} \\ C_{P1} \text{ for } H_1 \end{cases}$
H_1^2	C_{P1} (see Note 1)	1	C_{P1} (see Note 1)

Notes:

- (1) For the events G_1^2 or $G_1 \cdot H_1$ or H_1^2 [$G_1 \cdot H_1^2$ or $G_1^2 \cdot H_1$], the correlation test C_{P1} is formed on any H_1 pulses, and the correlation test $C_{P1} \cdot \bar{C}_Q$ is formed on any G_1 pulses, and if either [any] pulse passes the correlation test, that pulse shall be associated with the P-reply with high confidence and used to update its monopulse average.
- (2) The SPI pulse decoding shall also use the above rules for both the pulse decode decision and the confidence bit.

The outputs of the AARTU are:

- (a) Lower 8 bits of antenna boresight azimuth at bracket detection (3.4.5.4.1).
- (b) Reply range estimate (range unit word, 3.4.13.3.2).
- (c) Control signal to enable the sample control logic for ATCRBS processing.
- (d) Control signal to enable/inhibit bracket declaration.
- (e) Mode type transmitted (3.4.2.1.1).

3.4.5.4.1 Antenna azimuth determination.- The state of the antenna azimuth register shall be sampled when a valid bracket pair is declared. The lower 8-bits of the antenna azimuth word shall be part of the reply report passed to the reply correlator.

3.4.5.4.2 Range determination.- The ATCRBS, ATCRBS/Mode S or ATCRBS only All-Call listening interval shall be defined by the transmission time and the length of the listening window. The Reply processor shall provide the 23 bits of station time at the occurrence of a P₃ pulse and the lower 16 bits of station time at bracket detection. The reply correlator will use these to perform a range calculation. The station time at the time of a P₃ pulse will be provided as part of a sweep message. The lower 16 bits of station time at bracket detection shall be part of the reply report passed to the reply correlator.

3.4.5.4.3 Mode indication.- The interrogation mode corresponding to the range interval being processed shall be part of each reply report generated during the range interval.

3.4.5.4.4 Control signals.- When ATCRBS and Mode S All-Call listening windows overlap the monopulse channel A/D converter shall be time-shared between ATCRBS and Mode S reply processing, with Mode S All-Call replies taking precedence. During this interval, the monopulse A/D converter and SLS video digitizer sampling times shall be controlled by the sampling control logic (3.4.5.2.2), except when a Mode S preamble is detected, whereupon the sampling control of the monopulse A/D converter and the SLS video digitizer shall be controlled by the Mode S reply processor until the entire Mode S data block has been sampled, before returning control back to the ATCRBS processor sampling control logic.

The ATCRBS bracket detector shall be enabled only during the defined ATCRBS, ATCRBS/Mode S or ATCRBS-only All-Call listening period, except that it shall inhibit bracket detection for 26 μ s beyond the end of a Mode S reply data block.

3.4.5.5 Reply processor/correlator data transfer.- The data extracted from mainbeam ATCRBS replies shall be transmitted to the reply correlator for further processing in the form of messages corresponding to individual replies.

At the start of each ATCRBS sweep, a message termed the initial message shall be transmitted from the reply processor to the reply correlator containing:

- (a) Mode type transmitted (3.4.2.1.1)
- (b) Time-of-day (3.4.13.2.2)
- (c) Overload indication

For each mainbeam ATRBS reply detected during the listening period, a message shall be transmitted from the reply processor to the reply correlator containing at least the following information:

- (a) Mode indicator (3.4.2.1.1)
- (b) Reply range, ρ (Range unit word, 3.4.13.3.2)
- (c) Reply monopulse average, ϕ (3.4.5.3.2.6)
- (d) Antenna boresight azimuth at bracket detection, θ (3.4.5.4.1)
- (e) Reply code estimate (including X, SPI) denoted by $E^+ = (E_1, E_2, \dots, E_{14})$ where E^+ is obtained by rearranging pulses as in 3.4.5.3.3.3
- (f) Code pulse confidence level sequence denoted by $F^+ = (F_1, F_2, \dots, F_{14})$ where F^+ is obtained by rearranging pulses as in 3.4.5.3.3.3.

The 14-bit code pulse estimate shall consist of either a 12-bit discrete code or a 12-bit altitude readout depending on the mode transmitted, and the X and SPI pulse estimates, with the overall ordering of these bits as specified in 3.4.5.3.3.3. The 14-bit confidence level sequence shall be rearranged according to this same transformation, and shall also include confidence level indication for the X and SPI pulse estimates.

3.4.5.6 Reply correlation.- A decoded ATRBS reply accepted from the reply processor shall be compared in range, azimuth, and high confidence (mode A or mode 2) code or altitude bits with previously received replies, so that all mode 2, A and C replies from a single target are grouped into a single target report.

3.4.5.6.1 Target azimuth estimation.- The reply correlation operation shall be preceded by the calculation of the reply azimuth estimate ψ for each decoded reply (where ϕ is not zero) in terms of the antenna boresight azimuth θ and a monopulse average for the reply.

The off-boresight angle for the reply shall be determined by using the off-boresight look-up table (3.4.11.2). The off-boresight angle for a particular value of off-boresight signal shall be stored as an entry in the look-up table.

The index value IN shall be computed as follows:

$$IN = \bar{\phi} + \Delta_m$$

where $\bar{\phi}$ is the monopulse average and Δ_m is the table offset value supplied by performance monitoring (3.4.10). The resulting value of IN is checked against parameters MBL and MBH (3.4.1.6.5.3.2) to determine if the reply was received within the antenna main lobe or beyond the beam edge. If IN lies within the range MBL to MBH, the reply shall be accepted as a mainbeam reply. If IN lies outside this range, the reply shall be discarded. If the reply is accepted, the off-boresight angle $f(\bar{\phi} + \Delta_m)$ shall be retrieved from the off-boresight look-up table. The target azimuth estimate for a reply is defined as:

$$\Psi = \theta + f(\bar{\phi} + \Delta m)$$

and the Boresight Flag (BF) shall be set equal to zero. If $\bar{\phi} = 0$, then $\Psi = \theta$ and BF shall be set equal to one.

3.4.5.6.2 Wide pulse resolution.- If an aircraft transponder fails to meet the pulse width specification, its reply may incorrectly be called two overlapping replies by the reply processing subsystem. To correct this error, all replies i of the following type shall be marked by having a Wide Pulse Flag (WF) set to one:

- (a) $\rho_i - \rho_{i-1} \leq \rho_w$ and,
- (b) $|\psi_i - \psi_{i-1}| \leq \psi_w$ and,
- (c) code of i is a subset of the code of $i-1$, that is, $|E_i \cdot \bar{E}_{i-1}| = 0$.

where:

subscript i denotes the i -th reply
 subscript $i-1$ denotes the reply preceeding the i -th reply
 subscript w denotes "associated with wide pulse"
 ρ denotes range estimate
 ψ denotes azimuth estimate
 $\rho_w = 12(6-66,3) \text{ Ru}$
 $\psi_w = 8(4-64,4) \text{ Au}$

Any reply failing any part of this test shall have its WF set to zero. Reports formed by wide pulse replies will be discarded at declaration time (3.4.5.6.7).

3.4.5.6.3 Operations with binary sequences; notation.- Specification of logical operations to be performed on the 12-bit reply code estimate, obtained from E^+ and denoted $E = (E_1, E_2, \dots, E_{12})$ and the 12-bit confidence bit sequence, obtained from F^+ and denoted $F = (F_1, F_2, \dots, F_{12})$, will use the following conventional mathematical definitions. The X and SPI bits will not be used in any of these operations.

- (a) The sum modulo-2 of two binary sequences

$$A = (A_1, A_2, \dots, A_n)$$

$$B = (B_1, B_2, \dots, B_n)$$

is denoted as:

$$A \oplus B = (A_1 \oplus B_1, \dots, A_n \oplus B_n)$$

where $A \oplus B$ denotes the logical 'exclusive OR' operation with components A_i and B_i .

- (b) The dot product $A \cdot B$ is defined as

$$A \cdot B = (A_1 \cdot B_1, \dots, A_n \cdot B_n)$$

where $A_1 \cdot B_1$ denotes the logical AND operation with components A_1 and B_1 .

- (c) The logical sum $A + B$ of two binary sequences is defined as

$$A + B = (A_1 + B_1, \dots, A_n + B_n)$$

where $A_1 + B_1$ denotes the logical OR operation with components A_1 and B_1 .

- (d) The magnitude of a binary sequence, $|A|$ is defined as the number of '1's in the sequence.

- (e) The complement of a binary sequence, \bar{A} , is defined as

$$\bar{A} = (\bar{A}_1, \dots, \bar{A}_n)$$

where \bar{A}_1 denotes the complement of A_1 .

Note: Logical AND (\cdot) operations shall be performed prior to logical OR ($+$) operations.

3.4.5.6.4 Initial target report. - Each decoded ATCRBS reply passed to the correlator that fails to correlate with an existing target report shall result in the formation of an initial target report. The contents of the initial report, indexed by k , resulting from the decoded reply, indexed by i , are as follows:

- (a) Range estimate $\rho(k) = \rho(i)$ Note: the caret (^) denotes a report value.
- (b) Azimuth estimate $\psi(k) = \psi(i)$
- (c) $BF(k) = BF(i)$
- (d) Mode A code estimate, denoted $A^k = (A_1, \dots, A_{12})$ and Mode A code confidence bits, denoted $B^k = (B_1, \dots, B_{12})$:

Case 1: If reply i was a Mode A reply,
 $A^k = E^i$ and $B^k = F^i$.

Case 2: If reply i was a Mode C reply,
 $|A^k| = 12$ and $|B^k| = 0$

Case 3: If reply 1 was a Mode 2 reply,
 $|A^k| = 12$ and $|B^k| = 0$.

(e) Altitude code estimate, denoted $C^k = (C_1, \dots, C_{12})$ and altitude code confidence bits, denoted $D^k = (D_1, \dots, D_{12})$:

Case 1: If reply 1 was a Mode A reply,
 $|C^k| = 12$ and $|D^k| = 0$.

Case 2: If reply 1 was a Mode C reply,
 $C^k = E^1$ and $D^k = F^1$.

Case 3: If reply 1 was a Mode 2 reply,
 $|C^k| = 12$ and $|D^k| = 0$.

(f) Mode 2 estimate, denoted $G^k = (G_1, \dots, G_{12})$ and Mode 2 code confidence bits, denoted $H^k = (H_1, \dots, H_{12})$:

Case 1: If reply 1 was a Mode A reply,
 $|G^k| = 12$ and $|H^k| = 0$.

Case 2: If reply 1 was a Mode C reply,
 $|G^k| = 12$ and $|H^k| = 0$.

Case 3: If reply 1 was a Mode 2 reply,
 $G^k = E^1$ and $H^k = F^1$.

(g) Number of Mode A, 2, and C replies correlated, denoted by N_A , N_2 , and N_C , respectively:

Case 1: If reply 1 was a Mode A reply,
 $N_A = 1$, $N_C = 0$, $N_2 = 0$.

Case 2: If reply 1 was a Mode C reply,
 $N_A = 0$, $N_C = 1$, $N_2 = 0$.

Case 3: If reply 1 was a Mode 2 reply,
 $N_A = 0$, $N_C = 0$, $N_2 = 1$.

- (h) SPI estimate, denoted $SPI(k)$, and SPI confidence estimate, denoted $SPIC(k)$:

Case 1: If reply 1 was a Mode A reply,

$$SPI(k) = E_{14}, SPIC(k) = F_{14}.$$

Case 2: If reply 1 was a Mode C or Mode 2 reply,

$$SPI(k) = 0, SPIC(k) = 0.$$

- (i) X estimate, denoted $X(k)$, and X confidence estimate, denoted $XC(k)$:

Case 1: If reply 1 was a Mode A reply,

$$X(k) = E_{13}, XC(k) = F_{13}.$$

Case 2: If reply 1 was a Mode C or Mode 2 reply,

$$X(k) = 0, XC(k) = 0.$$

- (j) $WF(k) = WF(1)$

3.4.5.6.5 Reply correlation conditions.- No reply shall be included in more than one target report. If a choice of target reports exists for a reply, the first target report considered shall be used.

A reply, indexed by m , shall be used to update a target report, indexed by k , if all of the following conditions are satisfied:

- (a) Target report k does not include any replies from the sweep containing reply m .

(b) $|\rho(k) - \rho(m)| < \Delta\rho.$

- (c) $|\varphi(k) - \varphi(m)| < \Delta\varphi.$ This condition shall only be required if $\hat{BF}(k)$ and $BF(m)$ both equal zero.

- (d) Code correlation:

Case 1: If reply m is a Mode A reply,

$$|(A^k \oplus E^m) \cdot F^m \cdot B^k| = 0.$$

Case 2: If reply m is a Mode C reply,

$$|(C^k \oplus E^m) \cdot F^m \cdot D^k| < 1.$$

Case 3: If reply m is a Mode 2 reply,

$$|(G^k + E^m) \cdot F^m \cdot H^k| = 0$$

Provision shall be made to vary the parameters $\Delta\rho$ and $\Delta\bar{V}$ as follows:

$$\Delta\rho = 8 \text{ Ru } (1 -64, 1)$$

$$\Delta\bar{V} = 16 \text{ Au } (4 -64, 4)$$

3.4.5.6.6 Target report updating. - If reply m correlates with target report k, then the contents of report k shall be updated with the data from reply m according to the following rules. (The notation $x \rightarrow y$ is used to denote that "the quantity x is replaced by the quantity y".)

(a) Range estimate

$$\underline{BF(k) = 0, BF(m) = 0}$$

Case 1: If $\rho(k)$ includes replies on both sides of antenna boresight, leave $\rho(k)$ unchanged,

Case 2: If $\rho(k)$ includes replies on one side of antenna boresight, and reply m is on the same side of boresight, $\rho(k)$ is set equal to the range estimate from the reply closest to boresight,

Case 3: If $\rho(k)$ includes replies only on one side of antenna boresight and reply m is on the other side of boresight

$$\rho(k) \rightarrow \frac{\rho(k) + \rho(m)}{2}$$

$$\underline{BF(k) = 0, BF(m) = 1}$$

$\rho(k)$ is unchanged

$$\underline{BF(k) = 1, BF(m) = 0}$$

$$\rho(k) \rightarrow \rho(m)$$

$$\underline{BF(k) = 1, BF(m) = 1}$$

$$\rho(k) \rightarrow \frac{(N_A + N_C + N_2) \rho(k) + \rho(m)}{N_A + N_C + N_2 + 1}$$

(b) Azimuth estimate: $BF(k) = 0, BF(m) = 0$

$$\underline{BF(k) = 0, BF(m) = 0}$$

Case 1: If $\hat{\Psi}(k)$ includes replies on both sides of antenna boresight, leave $\hat{\Psi}(k)$ unchanged.

Case 2: If $\hat{\Psi}(k)$ includes replies only on one side of antenna boresight, and reply m is on the same side of boresight, $\hat{\Psi}(k)$ is set equal to the azimuth estimate from the reply closest to boresight.

Case 3: If $\hat{\Psi}(k)$ includes replies only on one side of antenna boresight and reply m is on the other side of boresight,

$$\hat{\Psi}(k) \leftarrow \frac{\hat{\Psi}(k) + \hat{\Psi}(m)}{2}$$

For all cases, $BF(k)$ is unchanged.

$$\underline{BF(k) = 0, BF(m) = 1}$$

$\hat{\Psi}(k)$ is unchanged

$BF(k)$ is unchanged

$$\underline{BF(k) = 1, BF(m) = 0}$$

$$\hat{\Psi}(k) \leftarrow \hat{\Psi}(m)$$

$$BF(k) \leftarrow 0$$

$$\underline{BF(k) = 1, BF(m) = 1}$$

$$\hat{\Psi}(k) \leftarrow \frac{(N_A + N_C + N_2) \hat{\Psi}(k) + \hat{\Psi}(m)}{N_A + N_C + N_2 + 1}$$

$BF(k)$ is unchanged

(c) If reply m is a Mode A reply:

$$A^k + (A^k \cdot E^m) + (A^k \cdot B^k) + (E^m \cdot F^m)$$

$$B^k + B^k + F^m$$

$$N_A = N_A + 1$$

$$C^k, D^k, N_c \text{ unchanged}$$

$$G^k, H^k, N_2 \text{ unchanged}$$

(d) If reply m is a Mode C reply

$$A^k, B^k, N_A \text{ unchanged}$$

$$C^k + (C^k \cdot E^m) + (C^k \cdot D^k) + (E^m \cdot F^m)$$

$$D^k + D^k \cdot \overline{F^m} + \overline{D^k} \cdot F^m + C^k \cdot D^k \cdot E^m \cdot F^m + \overline{C^k} \cdot D^k \cdot \overline{E^m} \cdot F^m$$

$$N_c + N_c + 1$$

$$G^k, H^k, N_2 \text{ unchanged}$$

(e) If reply m is a Mode 2 reply:

$$A^k, B^k, N_A \text{ unchanged}$$

$$C^k, D^k, N_c \text{ unchanged}$$

$$G^k + (G^k \cdot E^m) + (G^k \cdot H^k) + (E^m \cdot F^m)$$

$$H^k + H^k + F^m$$

$$N_2 + N_2 + 1$$

(f) SPI estimate: If reply m is a Mode A reply:

$$SPI(k) + (SPI(k) \cdot E_{14}) + (E_{14} \cdot F_{14}) + (SPI(k) \cdot SPIC(k))$$

$$SPIC(k) + SPIC(k) \cdot \overline{F_{14}} + \overline{SPIC(k)} \cdot F_{14} + SPI(k) \cdot SPIC(k) \cdot E_{14} \cdot F_{14}$$

$$+ \overline{SPI(k)} \cdot SPIC(k) \cdot \overline{E_{14}} \cdot F_{14}$$

- (g) X pulse estimate: If reply m is a Mode A reply:

$$X(k) \leftarrow (X(k) \cdot E_{13}) + (E_{13} \cdot F_{13}) + (X(k) \cdot XC(k))$$

$$XC(k) \leftarrow XC(k) \cdot \overline{F}_{13} + \overline{XC}(k) \cdot F_{13} + X(k) \cdot XC(k) \cdot E_{13} \cdot F_{13} + \\ \overline{X}(k) \cdot XC(k) \cdot \overline{E}_{13} \cdot F_{13}$$

- (h) Wide Pulse Flag Update: $\hat{WF}(k) \leftarrow \hat{WF}(k) \cdot WF(1)$

3.4.5.6.7 Target report declaration.- A target report shall be composed of replies from no more than R successive sweeps. That is, when the first reply of a target report was received $R-1$ sweeps prior to the current sweep, the target report shall be considered a candidate for final declaration. The parameter R shall be a function of the PRF, the antenna beamwidth, and the antenna rotation rate. The parameter R shall not exceed the number of interrogations in twice the 3 dB beamwidth of the I pattern of the sensor.

The following conditional actions shall occur at target report declaration:

- (1) A target report, indexed by m , shall be discarded if $WF(m) = 1$.
- (2) A target report that is a candidate for final declaration shall be declared a final target report and transmitted by reply correlation to the surveillance processing function if its range exceeds the ATRBS processing delay, $D7$ defined in section 3.4.6.3.4, and it meets either of the following conditions:
 - (a) It contains 2 or more replies.
 - (b) There exists another target report n (already declared or still current) such that

$$|\hat{\rho}(m) - \hat{\rho}(n)| < \Delta\rho$$

$$|\hat{\gamma}(m) - \hat{\gamma}(n)| < \Delta\gamma.$$

- (3) Candidate target reports failing both of these conditions shall be discarded. However, provision shall be made to change this feature by specification of a software parameter, the setting of which results in all single hit target reports being declared without checking condition (b) above.

- (4) All candidate target reports meeting condition (b), whether or not satisfying condition (a), shall cause the single bit in the code swap field of the ATCRBS Target Report Data Block, Fig. 3.4.5-5, to be set.
- (5) Candidate target reports for which no reply has had a monopulse estimate made (i.e., for which the boresight flag BF(m), is set to 1 at the time of declaration) shall cause the single bit in the boresight azimuth indicator of the ATCRBS target report data block, Fig. 3.4.5-5, to be set.

The reply correlator shall be able to accept in real time the replies from aircraft bunched in accordance with 3.3.2.5(b) along with mainlobe fruit occurring at a rate which would produce 8 fruit replies in a 200 nmi sweep. It shall be able to process them according to the preceding reply/reply correlation algorithm at a rate of 40 replies per sweep. A build up of unprocessed targets, to be completed as soon as possible during the remainder of the 11 1/4° sector, is thereby permitted. The reply correlator shall have provision for accumulating up to 10 replies per aircraft per scan.

3.4.5.7 Target report output.- A final ATCRBS target report shall transmit the following information to the surveillance processing function (see fig. 3.4.5-5):

Each target report may be output from the reply correlator in real time (as soon as it is completely assembled) or target reports from a geographic sector of coverage may be buffered and transmitted in a block to the surveillance processing function, but the maximum delay for any target report shall not exceed 1/32 of a scan.

3.4.5.8 Beacon strobe generation.- The initial message received from the reply processor (3.4.5.5) shall be checked each sweep for the presence of a processor-overload flag, FO. When a transition from FO = 0 to FO = 1 is detected on successive sweeps, the boresight azimuth of the current sweep shall be stored and labeled B_S.

When the next transition from FO = 1 to FO = 0 is detected, the boresight azimuth of the current sweep shall be stored and labeled B_E. A beacon strobe report containing B_S and B_E shall be formatted and output to the performance monitoring function (3.4.10) within 1/32 scan.

This space unused intentionally.

Range Estimate	(Range unit word, 3.4.13.3.2)
Azimuth Estimate	(3.4.5.6.6(b))
Boresight Azimuth Indicator	(3.4.5.6.7(4))
Mode A Code Estimate	(3.4.5.6.6(c))
Mode A Confidence Sequence	(3.4.5.6.6(c))
Number of Mode A Replies Correlated	(3.4.5.6.6(e))
Mode C Code Estimate	(3.4.5.6.6(d))
Mode C Confidence Sequence	(3.4.5.6.6(d))
Number of Mode C Replies Correlated	(3.4.5.6.6(e))
Altitude Type	(3.4.6.3.4(c))
Mode 2 Code Estimate	(3.4.5.6.6(e))
Mode 2 Confidence Sequence	(3.4.5.6.6(e))
SPI Estimate	(3.4.5.6.6(f))
SPI Confidence	(3.4.5.6.6(f))
X Estimate	(3.4.5.6.6(g))
X Confidence	(3.4.5.6.6(g))
Time-of-Day of Most Recent Interrogation	(3.4.13.2.2)
Potential Code Swap Indicator	(3.4.5.6.7(3))

Fig. 3.4.5-5. ATCRBS Target Report Data Block Contents.

This space unused intentionally.

3.4.6 Surveillance processing.

3.4.6.1 Overview.- Surveillance processing shall generate reliable and accurate ATCRBS and Mode S reports from transponder replies, and from primary radar reports input from sources such as the CD and the MTD.

An ATCRBS report consists of merged replies. Individual reports are characterized by range, azimuth and Mode A code, Mode 2 code, and Mode C code (altitude). A report may be incomplete, if one or more of these quantities is absent or inconsistent. The sensor shall merge incomplete reports for the same aircraft, correlate reports to track data, update surveillance files on a scan-to-scan basis, and predict target positions. It shall also attempt to reinforce beacon reports with primary radar reports; and shall use primary reports to update track data files which have not been updated with correlating beacon data for the current scan. The sensor shall determine which of the reports that do not correlate with existing track data represent fruit, and which should be used to initiate new tracks.

The best reply position shall be selected for a Mode S equipped aircraft. All-Call replies that do not correlate with existing Mode S tracks and are not false targets shall be used to initiate tracks. Roll-Call replies shall be used to update the track's data base and to predict the track's next position for roll-call scheduling. After the track is updated, correlated and uncorrelated replies shall be made available to other users.

3.4.6.1.1 Surveillance processing for ATCRBS.- A principal technique for achieving high quality ATCRBS reports relies upon scan-to-scan processing. In the Mode S sensor a track file shall be established for each ATCRBS aircraft, and reports from each scan shall be compared with the track file. As a result of these comparisons, the report shall be verified, corrected and completed as necessary. Then the track shall be updated for use next scan.

An ATCRBS report consists of a merging of one or more replies. These individual replies are characterized by range, azimuth and either mode A code, mode 2 code or altitude. Depending upon whether some or all of these quantities are present and consistent for all replies, the merged report can be deficient in some attributes.

Section 3.4.6.4.6.3 checks for nearby reports that have swapped their 4096 code and altitudes. This can happen for instance if the transponder delay is different for mode A and mode C. Then the reply correlator can declare two reports - one consisting of the mode A replies of one target and the mode C replies of the other and the second of the opposite combination. Other events such as fruit and code declaration errors cause similar situations. The process specified in 3.4.6.4.6.3 looks for multiple reports very close in range and azimuth that associate with a stored track. If suitable comparisons hold, the correct report can be reconstructed by appropriate swapping of 4096 code. These corrections shall be made only after an association is achieved with a stored track.

The report-to-track correlation shall be based upon the several attributes of the report. A report is said to be associated to a track if it falls within a specified ρ , θ , h association interval. There are four cases to be considered:

- 1 on 1: Only one report associated with only one track. Section 3.4.6.4.7.
The report is correlated with the track.
- 1 on n: Only one report associated with n tracks. Section 3.4.6.4.9.
- m on 1: Only one track associated with m reports. Section 3.4.6.4.8.
- m on n: m reports associated with n tracks. Section 3.4.6.4.10.

In the last three cases, the report and track to be correlated are based upon the following factors in order of precedence:

- code agreement
- coarse distance parameters
- number of replies in report
- altitude agreement
- track maturity
- fine distance parameters.

After reports are correlated with stored tracks, the code is reviewed. If the 4096 code of the report does not match the track, it is assumed that a code change has been made in the aircraft and a transition situation is noted. After 3 successive scans of receiving the new code, the track file code is updated (3.4.6.6.6).

Other anomalous conditions are checked for and corrected in subsequent sections, following correlation. ATCRBS fruit are rejected in 3.4.6.7. False target flagging is accomplished partly in 3.4.6.4.16 and partly in 3.4.6.13. A block diagram of surveillance processing for ATCRBS is shown in fig. 3.4.6-1.

Throughout section 3.4.6 all reference to ATCRBS 4096 code shall be interpreted to mean mode A code. Where mode 2 code is intended it will be stated explicitly.

3.4.6.1.1.1 ATCRBS subfunctions.- There shall be nine subfunctions (excluding radar/beacon correlation and surveillance data dissemination), referred to herein as:

- | | |
|--|--------------|
| (a) ATCRBS preprocessing | (3.4.6.3.4) |
| (b) ATCRBS target-to-track correlation | (3.4.6.4) |
| (c) False-to-real track conversion | (3.4.6.4.16) |
| (d) ATCRBS one-hit report rejection | (3.4.6.4.13) |
| (e) ATCRBS track initiation | (3.4.6.5) |
| (f) False target report/track flagging | (3.4.6.5.4) |
| (g) ATCRBS track update | (3.4.6.6) |
| (h) ATCRBS fruit rejection | (3.4.6.7) |
| (i) ATCRBS track data message processing | (3.4.6.11) |

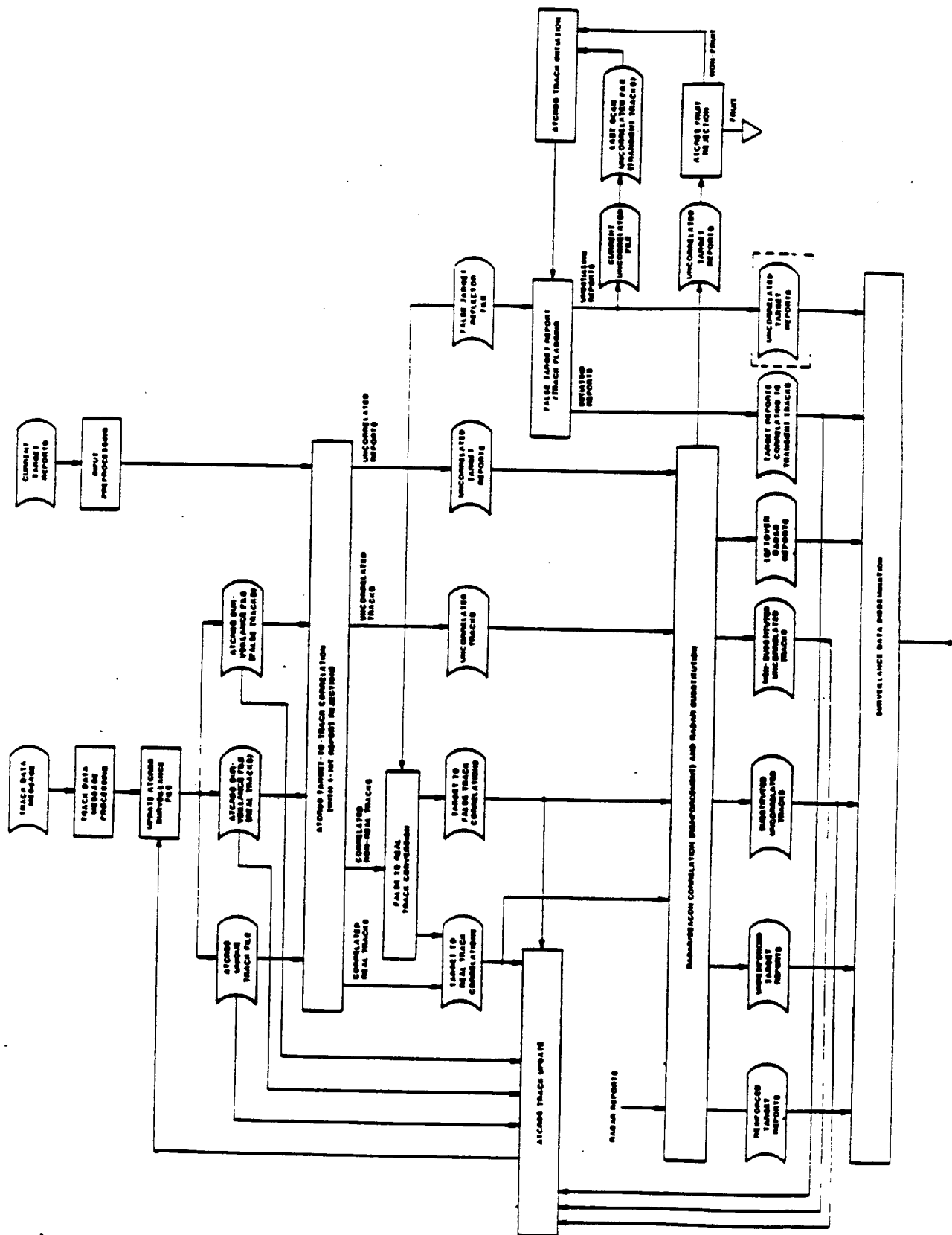


FIG. 3.4.6 -1. SURVEILLANCE PROCESSING FOR ATRBS

3.4.6.1.1.2 Input files.- There shall be five input files, referred to herein as:

- (a) ATCRBS surveillance file (false tracks, real tracks, and unique code tracks)
- (b) Current target reports file
- (c) Last-scan uncorrelated file
- (d) False target reflector file
- (e) Track data message file

3.4.6.1.1.3 Output files.- There shall be four output files, referred to herein as:

- (a) Uncorrelated tracks file
- (b) Target/track correlation file (false and real)
- (c) Last-scan uncorrelated file
- (d) Updated ATCRBS surveillance file

3.4.6.1.1.4 Operation.- All subfunctions may be performed on a track or sector basis, but shall be performed at least once per sector and in the order shown in fig. 3.4.6-1. A sector shall be 11.25 degrees (512 Au). If processing is performed by sectors, due account shall be taken of cases where inputs to certain functions lie near the boundaries of adjacent sectors. In particular, some target reports may be held until the next sector to handle boundary problems. Track data message processing shall be performed within 1/16 scan of the receipt of any track data message.

- (a) ATCRBS target-to-track correlation and false-to-real track conversion shall receive current scan target reports and make spatial (plus altitude and ATCRBS code) correlations to existing tracks in the surveillance file, as specified in 3.4.6.4. Target-to-track correlations shall be used in ATCRBS track update. The correlated reports shall be inputted to radar/beacon correlation (3.4.6.12) along with uncorrelated tracks. Uncorrelated one-hit reports shall be discarded.
- (b) ATCRBS fruit rejection shall discard target reports under conditions specified in 3.4.6.7
- (c) ATCRBS track initiation and false target report/track flagging shall attempt to initiate new tracks by correlating, on a scan-to-scan basis, those target reports that did not correlate with existing tracks, as specified in 3.4.6.5, and that were not discarded as fruit.
- (d) ATCRBS track update shall update tracks using ATCRBS target reports or radar reports, as specified in 3.4.6.6.
- (e) Track data message processing shall reinitiate tracks based on track data messages, as specified in 3.4.6.11.

3.4.6.1.2 Surveillance processing for Mode S.- Mode S, like ATRBS, also relies on scan-to-scan processing for high quality surveillance data. This processing, though, is considerably simplified by the presence of a unique target ID. Thus, in particular, the report-to-track association and correlation functions are not required. A block diagram of surveillance processing for Mode S is shown in fig. 3.4.6-2.

3.4.6.1.2.1 Mode S subfunctions.- There shall be six subfunctions (excluding radar/beacon correlation and surveillance data dissemination), referred to herein as:

- | | |
|---|-------------|
| (a) Mode S preprocessing | (3.4.6.3.5) |
| (b) Mode S position measurement selection | (3.4.6.8) |
| (c) Mode S track initiation | (3.4.6.9) |
| (d) mode S false track rejection | (3.4.6.9) |
| (e) Mode S track update | (3.4.6.10) |
| (f) Mode S track data message processing | (3.4.6.11) |

3.4.6.1.2.2 Mode S input files.- There shall be six input files, referred to herein as:

- (a) Mode S roll-call reply buffer.
- (b) All-Call reports file.
- (c) Mode S surveillance file.
- (d) Track data message file.
- (e) Radar/uncorrelated Mode S track file.
- (f) Last-scan uncorrelated file

3.4.6.1.2.3 Mode S output files.- There shall be four output files, referred to herein as:

- (a) Updated Mode S surveillance file.
- (b) Reply/report track correlation file.
- (c) Uncorrelated tracks file.
- (d) Last-scan uncorrelated file.

3.4.6.1.2.4 Operation.- Mode S position measurement selection and correlation shall be completed before radar/beacon correlation is performed. (Radar/beacon correlation shall be performed at least once per azimuth sector as specified in 3.4.6.12.) Mode S track update shall be performed at least once per azimuth sector after radar/beacon correlation. Mode S track initiation shall be performed within 3/4 of a scan of the receipt of a second correlating reply as specified in 3.4.6.9. Track data message processing shall be performed within 1/16 scan of receipt of any track data message.

- (a) Mode S position measurement selection shall receive roll-call replies and All-Call replies for a given ID and select one such reply following the rules specified in 3.4.6.8. A correlation based on

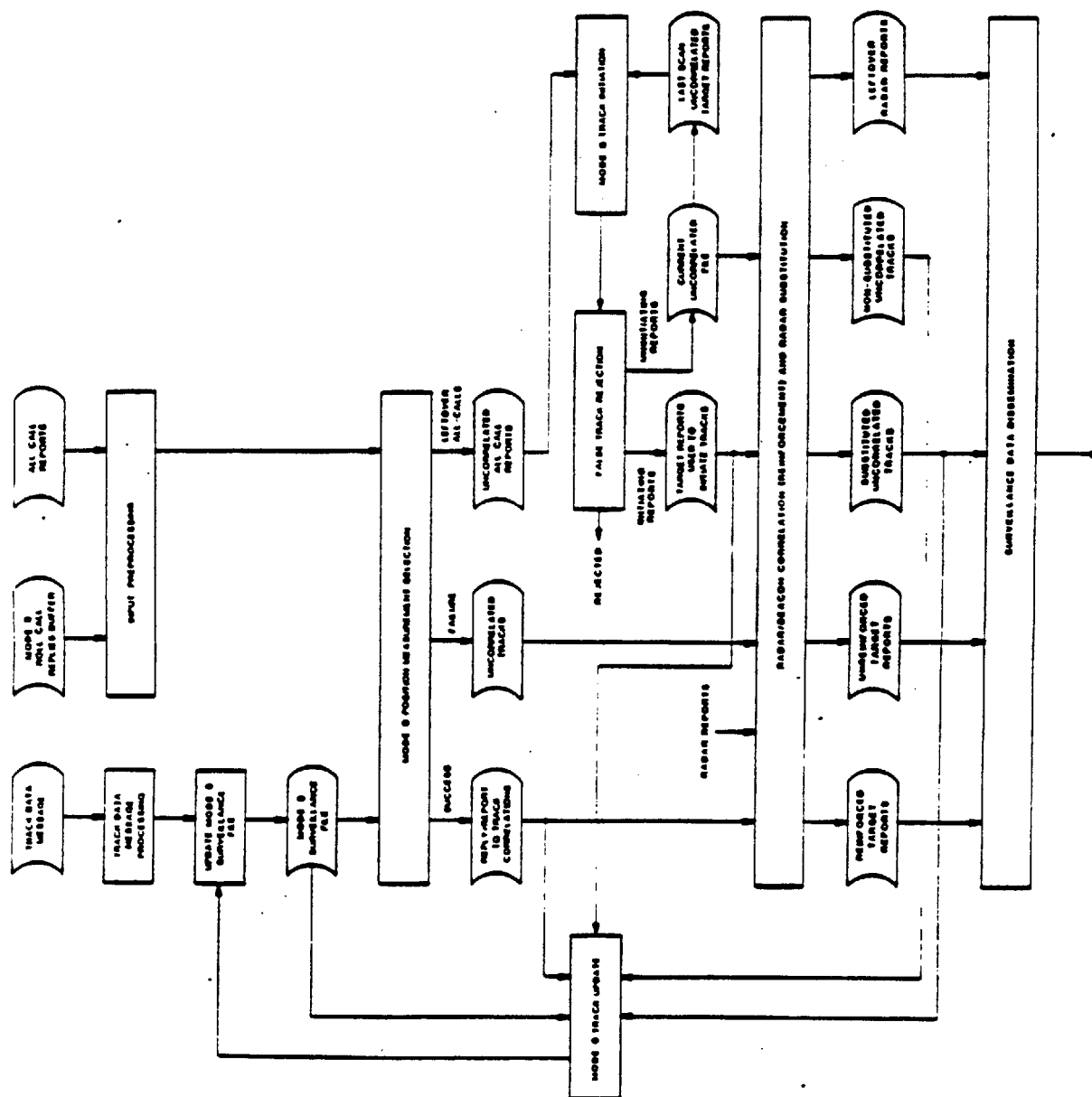


FIG. 3.4.6 -2. SURVEILLANCE PROCESSING FOR MODE S

Mode S ID shall be attempted and the reply shall be entered into the appropriate file as shown in the diagram. Tracks not receiving a reply shall be an input to radar/beacon correlation.

- (b) Mode S track initiation shall receive uncorrelated All-Call reports and attempt track initiation as specified in 3.4.6.9. Tracks that this function considers false shall be dropped. Tracks considered as real shall be entered into the surveillance file.
- (c) Mode S track update shall use roll-call replies, All-Call reports, and radar returns as specified in 3.4.6.10. To the extent possible, all tracking functions (Mode S and ATCRBS) shall be implemented with the same computer program.
- (d) Track data message processing shall initiate or update tracks based on track data messages, as specified in 3.4.6.11.

3.4.6.1.3 Radar/beacon correlation.- Radar reports shall be correlated to ATCRBS and Mode S beacon reports and to beacon uncorrelated tracks. The output shall be radar reinforced and unreinforced beacon reports, radar reports correlated to beacon uncorrelated tracks, and uncorrelated radar reports. Correlation shall be done by azimuth sectors. Radar/beacon correlation and ATCRBS target-to-track correlation shall, to the extent possible, be implemented with the same computer program.

3.4.6.1.4 Surveillance data dissemination.- The data dissemination function shall format beacon reports and tag each with a sensor primary indication. These reports as well as primary radar reports shall be selectively disseminated to the ATC facilities as specified in 3.4.6.14.

3.4.6.2 Surveillance file.- The purpose of this file is to store items necessary for surveillance processing plus items necessary for other system functions. The surveillance file shall contain at least all of the items shown in Table 3.4.6.-1. These items are presented in the table with an indication of the functions that use the item, or set the item, or both.

This space intentionally unused.

TABLE 3.4.6-1.

SURVEILLANCE FILE

Field	Field Length	ATCRBS/ Mode S Use	C/M	S/P	D/L	N/M	P/M
Mode S ID	24 bits	MS	U	B	U	U	U
ATCRBS 4096 Code	14 bits	A/MS		B	B		
ATCRBS 4096 Code Confidence	14 bits	A		B			
Predicted Range	16 bits	A/MS	U	B			
Predicted Range Rate (or x)	16 bits	A/MS		B			
Range Guard	16 bits	MS	U	S			
Earliest Likely Range (Range Delay, D ₁)	16 bits	MS	U	S			
Predicted Azimuth	14 bits	A/MS		B			
Predicted Azimuth Rate (or y)	14 bits	A/MS		B			
Earliest Likely Azimuth	14 bits	MS	U	S			S
Latest Likely Azimuth	14 bits	MS	U	S			
Measured Range, D ₃	16 bits	A/MS		B		U	U
Measured Azimuth	14 bits	A/MS		B		U	U
Time of Measurement (3.4.13.2.2)		A/MS		S		U	
Track Position, x	16 bits	A/MS		B			
Track Position, y	16 bits	A/MS		B			
Turn state, p	2 bits	A		B			
Turn state, θ	2 bits	A		B			
Mode C Code or Altitude	12 bits	A/MS		B		U	U
Mode C Code or Altitude Confidence	12 bits	A		B			

S = Set By C/M = Channel Management (3.4.1)
 U = Used By S/P = Surveillance Processing (3.4.6)
 B = Both D/L = Data Link Processing (3.4.7)
 N/M = Network Management (3.4.8)
 P/M = Performance Monitoring (3.4.10)

TABLE 3.4.6-1.

SURVEILLANCE FILE (CONTINUED)

Field	Field Length	ATCRBS/ Mode S Use	C/M	S/P	D/L	N/M	P/M
Altitude Type Setting	4 bits	A		B			
Altitude Counter	3 bits	A		B			
Track Firmness	5 bits	A/MS		B		U	
History Track Firmness	5 bits	A/MS		B		U	
False Track Indicator	1 bit	A		B			
Code Transition Counter	3 bits	A		B			
Transition 4096 Code	14 bits	A		B			
Transition 4096 Code Confidence	14 bits	A		B			
Correlating Target Report Number	NS	A		B			
$\Delta\rho_{max}$	16 bits	A/MS		B			
$\Delta\theta_{max}$	14 bits	A/MS		B			
Sector Boundary Flag	1 bit	A/MS		B			
Pointer to Next Track	NS	A/MS	U	B			
Acquisition Track Indicator	1 bit	MS	U	B			
Test Track Indicator	1 bit	A/MS					B
Diffraction Flag	1 bit	A/MS		B			
Data Link Active							
Message File Pointer	NS	MS	U		B		

NS - Not Specified
 S - Set By
 U - Used By
 B - Both

C/M - Charnel Management (3.4.1)
 S/P - Surveillance Processing (3.4.6)
 D/L - Data Link Processing (3.4.7)
 N/M - Network Management (3.4.8)
 P/M - Performance Monitoring (3.4.10)

TABLE 3.4.6-1.
SURVEILLANCE FILE (CONTINUED)

Field	Field Length	ATCRBS/ Mode S Use	C/M	S/P	D/L	N/M	P/M
AI Bit	1 bit	MS	U	U	S		
DL Bit	1 bit	MS	U		S	S	
Reply Type	3 bits	MS		S		U	U
Basic Data Link Capability CA	3 bits	MS	U	S	U	B	
Extended Capability ECA With Assoc- iated BDS2	52 bits	MS			B	U	
Capability Request Flag CAP	1 bit	MS	U		B	S	
Broadcast message No.	2 bits	MS	B			S	
New Roll-Call Target	1 bit	MS		S	B	S	
Flight ID	48 bits	MS		S	B		
Target Track Status	3 bits	A/MS				B	
Primary Coordi- nation in Progress	1 bit	MS				B	
Sensor Data Request Bits	3 bits	A/MS				B	
Assigned Sensor (N items, $0 \leq N \leq 4$)	N x 4 bits	MS				B	
Request Bit for Assigned Sensor	N x 1 bits	MS				B	
Connectivity Flag for Assigned Sensor	N x 1 bits	MS				B	
Coverage Map Cell Index	8 bits	MS				B	
Zenith Cone Flag	1 bit	MS				B	
Special Mode Flag	1 bit	MS				B	
Inlist - Sensor ID (2 items)	2 x 4 bits	A/MS				B	

S - Set By
U - Used By
B - Both

C/M - Channel Management (3.4.1)
S/P - Surveillance Processing (3.4.6)
D/L - Data Link Processing (3.4.7)
N/M - Network Management (3.4.8)
P/M - Performance Monitoring (3.4.10)

TABLE 3.4.6-1.

SURVEILLANCE FILE (CONTINUED)

Field	Field Length	ATCRBS/ Mode S Use	C/M	S/P	D/L	N/M	P/M
Inlist-Sensor ID	2 x 1						
Act. Ind. (2 items)	bits	A/MS				B	
Outlist - Sensor ID	2 x 4						
(2 items)	bits	MS				B	
Outlist-Expiration Counter	3 bits	MS				B	
Outlist-Flag to Suspend Action	1 bit	MS				B	
Remote Track Number	2 x 12						
(2 items)	bits	A				B	
Target Closure Flag	1 bit	MS	S	U	B	U	U
New ELM Target Flag	1 bit	MS			B	S	
Sensor Priority Status PS	1 bit	MS	U	U	U	B	
Target Control Status UC	1 bit	A/MS				B	
Lockout Control State	2 bits	MS				B	
Lock Count	5 bits	MS				B	
Unlock Count	6 bits	MS				B	
All-Call Flag	1 bit	MS		S		U	
All-Call Count	6 bits	MS				B	
Unconnected Sensor Flag	1 bit	MS	U		U	S	
Connected Sensor Flag	1 bit	MS				B	
Radar Zenith Cone Flag	1 bit	A		U		S	
Spare Fields	32 bits						

S = Set By C/M = Channel Management (3.4.1)
 U = Used By S/P = Surveillance Processing (3.4.6)
 B = Both D/L = Data Link Processing (3.4.7)
 N/M = Network Management (3.4.8)
 P/M = Performance Monitoring (3.4.10)

3.4.6.3 Input preprocessing.

3.4.6.3.1 Purpose.- The purpose of this subfunction is to perform initial conversion and selection tasks on the ATCRBS, Mode S, and radar data that are input to surveillance processing.

3.4.6.3.2 Inputs.- The inputs to this subfunction shall include the following:

- (a) ATCRBS report data blocks from ATCRBS reply correlation (3.4.5).
- (b) Mode S reply data blocks (roll-call and All-Call) from the Mode S reply processor (3.4.4).
- (c) Radar report data blocks from the radar interface (3.5.2).
- (d) The off-boresight lookup table (3.4.11).
- (e) The table offset value from performance monitoring (3.4.10.3.5.2).
- (f) The ATCRBS/radar range mask table (3.4.8.3.6).
- (g) The collimation correction range and angle (3.4.10.3.5.3).

3.4.6.3.3 Outputs.- The outputs of this subfunction shall include the following:

- (a) ATCRBS report data blocks with corrected range and decoded altitude.
- (b) Mode S reply data blocks with corrected range, measured azimuth and the off-boresight angle. Altitude decoding shall be performed after position measurement selection (3.4.6.8).
- (c) Radar reports that are within the maximum sensor operating range, as defined by the ATCRBS/radar range mask table.

3.4.6.3.4 ATCRBS preprocessing.-

- (a) Target report reconstruction: an aircraft whose ATCRBS transponder fails to satisfy the inter-mode delay criterion can produce Mode A and Mode C replies sufficiently different in range to prevent them from correlating with each other by the rules of 3.4.5.6.5. To correct this problem, target reports of the following types are identified:

Type A: a target report with no Mode C altitude replies

Type C: a target report with no Mode A code replies

Whenever a pair of target reports, one of type A and the other of type C, are found that satisfy:

$$\begin{aligned} |p_A - p_C| &< 10 * \Delta p \text{ and} \\ |\psi_A - \psi_C| &< \Delta \psi \end{aligned}$$

where:

$$\Delta p = 8(1-64,1) R_u, \text{ and}$$

$$\Delta \psi = 16(4-64,4) A_u.$$

these two reports shall be combined into one report having the following information fields:

$$(1) \rho = \frac{\rho_A + \rho_C}{2}$$

$$(2) \psi = \frac{\psi_A + \psi_C}{2}$$

- (3) Mode A code of target report A
- (4) Mode A confidence of target report A
- (5) Number of Mode A replies of target report A
- (6) Mode C altitude of target report C
- (7) Mode C confidence of target report C
- (8) Number of Mode C replies of target report C
- (9), (10), (11) Mode 2 code, code confidence, and number of replies
 - (i) if only one report has Mode 2 replies, its Mode 2 code, code confidence, and number of replies shall be used;
 - (ii) if both reports have Mode 2 replies, and the two codes agree in all high confidence bits, the new target report shall contain:

$$\begin{aligned} C &= (C_A \cdot C_C) + (C_A \cdot D_A) + (C_C \cdot D_C) \\ D &= D_A + D_C \\ N_2 &= N_{2A} + N_{2C} \end{aligned}$$

where C and D are the vector Mode 2 code and code confidence words (refer to 3.4.5.6.3 and 3.4.5.6.6 for notation details).

- (iii) if both reports have Mode 2 replies, and the two codes disagree in one or more high confidence bits, the new target report shall contain:

$$\begin{aligned} |C| &= 0 \\ |D| &= 0 \\ N_2 &= N_{2A} + N_{2C} \end{aligned}$$

- (12) Time of day corresponding to most recent interrogation:

$$t = \text{Max}\{t_A, t_C\}$$

- (13) (14) SPI bit and SPI confidence:

$$\text{SPI} = \text{SPI}_A$$

$$\text{SPIC} = \text{SPIC}_A$$

(15), (16) X bit and X confidence:

$$X \leftarrow X_A$$

$$XC \leftarrow XC_A$$

(b) Range correction: range correction for ATCRBS shall be accomplished using the following equation:

$$\text{True range} = \text{measured range} - 48 \text{ Ru} (3 \text{ us}) - D_7$$

where 3 us is the ATCRBS transponder turnaround time, and D7 accounts for delays arising from a particular implementation.

True range shall be written in the measured range word of the reply data block.

(c) Altitude conversion: the altitude confidence bit estimates from the reply data block (see fig. 3.4.5-6) shall be tested in order to classify the altitude reply according to one of the first five of the nine altitude types listed in Table 3.4.6-2. "Type Setting" from this table shall be written into the designated field of the reply data block. Only if the altitude type is "clear flight level" (Type setting "0") shall the altitude field from the reply data block be decoded, expressed in units of 100 feet, and written into the altitude field of the reply data block. Altitude shall not be decoded for altitude types "1", "2", "3", and "4".

3.4.6.3.5 Mode S preprocessing.-

(a) Range correction: range for Mode S roll-call targets shall be computed from (i) the expected range delay, D_1 (from the target record, 3.4.1.3.4.1), (ii) the measured range correction D_2 (from the Mode S reply block, 3.4.4.8.2), (iii) the total turnaround delay for roll-call = 2124 Ru (132.75 us), and (iv) any other system delays arising from the particular hardware implementation, D_4 .

The true range for roll-call targets shall be computed as follows:

$$\text{true range} = D_1 + D_2 - (2124 + D_4).$$

Range for Mode S All-Call targets shall be computed from (a) the measured range, D_3 (from the Mode S reply block), (b) the transponder turn-around delay for ATCRBS/Mode S All-Call = 2080 Ru (130.0 us) and for Mode S-only All-Call = 2124 (132.75 us), and (c) system delays, D_4 (as defined herein).

TABLE 3.4.6-2
ALTITUDE REPRESENTATIONS
All values in Hex

<u>Altitude Type</u>	<u>Code</u>	<u>Confidence</u>	<u>Type Setting</u>
(1) No replies	000	000	2
(2) Garbled brackets	No high confid. '1's > 1 high confid. '0's > 1 low confid. bits	---	3
(3) Clear brackets	000	FFF	4
(4) Garbled flight level	all bits low confid, or > 1 high confid. '1's and > 1 low confid. bits	---	1
(5) Clear flight level	any but 000	FFF	0
(6) "Had been" no replies	000	000	A
(7) "Had been" brackets	000	000	D
(8) "Had been" garbled flight level	any but 000	000	E
(9) "Had been" clear flight level	any but 000	000	F

Note: An altitude is defined to be "garbled brackets" if it has no high confidence 1's in any code bit and thus may represent an aircraft not equipped with encoding altimeter.

The true range for All-Call targets shall be computed as follows:

$$\begin{aligned} \text{true range} &= D_3 - (2080 + D_4) \quad \text{ATCRBS/Mode S All Call Interrogation} \\ &= D_3 - (2124 + D_4) \quad \text{Mode S-Only All Call Interrogation} \end{aligned}$$

True range shall be written into the measured range word of the reply data block.

- (b) Azimuth lookup: if a monopulse estimate is present, the off-boresight angle for Mode S roll-call and All-Call reply blocks shall be determined by using the off-boresight lookup table. The off-boresight angle for a particular value of off-boresight signal is stored as an entry in the lookup table.

The index value IN shall be computed as follows:

$$IN = OBI + \Delta m$$

where OBI is the eight-bit off-boresight signal contained in the reply data block and Δm is the table offset value supplied by performance monitoring. The resulting value of IN is checked against parameters MBL and MBH (3.4.1.6.5.3.2) to determine if the reply was received within the antenna main lobe or beyond the beam edge. If IN lies within the range MBL to MBH, the reply shall be accepted as a main beam reply. If the reply is accepted, the off-boresight angle shall be retrieved from the off-boresight lookup table. This angle shall be entered in the reply data block in place of OBI.

Roll-call replies shall be discarded if IN lies outside the range. All-Call replies with IN outside this range or with no monopulse estimate shall be retained and a value of zero shall be inserted in the data block in place of OBI and a NO AZ flag shall be set for the reply.

Target azimuth shall be computed by adding the off-boresight azimuth to the antenna boresight azimuth contained in the reply data block. Target azimuth shall replace the boresight azimuth in the reply data block.

- (c) All-Call fruit elimination: each All-Call reply shall be retained for 8(4-8,1) ATCRBS/All-Call periods and checked to determine if it correlates with any other All-Call reply. Two All-Calls are correlated if:

- (1) Mode S addresses (if present) are the same, and
- (2) $|p_1 - p_2| < 8$ Ru (1-64,1) and
- (3) $|q_1 - q_2| < 16$ Au (4-64,4) if both replies contain off-boresight azimuth information (NO AZ=1) or $|q_1 - q_2| < 160$ Au (50-200,10) if either or both replies lack off-boresight azimuth information (NO AZ=1),

where ρ and θ are the reply range and azimuth respectively. Correlated sets of replies shall be retained if the set contains at least:

- (1) 2(2-4,1) replies with range, Mode S address and off-boresight azimuth,
- (2) 2(2-4,1) replies with at least range and Mode S address,
- (3) 2(2-4,1) replies with at least range and off-boresight, monopulse,
- (4) 3(2-4,1) replies with at least range.

All-Call replies not meeting the above criteria shall be discarded.

- (d) Alert check: each All-Call reply containing a Mode S address shall be checked to determine if its Mode S address is listed in the duplicate address alert table (DAAT, 3.4.6.9.4). An All-Call reply whose address is listed in the DAAT shall be used to update the DAAT as follows:

- (1) The All-Call reply position shall replace the position of the DAAT entry closest to the reply.
- (2) The corresponding counter shall be set to zero.

This All-Call reply shall be disseminated to ATC.

3.4.6.3.6 Radar preprocessing.- Reported range shall be converted into two-way (radar) range in sensor range units and corrected by adding the collimation correction range, CCR (3.4.10.3.5.3). Reported azimuth shall be corrected to sensor azimuth by adding the collimation correction angle, CCA, (3.4.10.3.5.3). The collimation corrected azimuth of each radar report shall be used to enter the ATCRBS/radar range mask table. The resulting table value will be the maximum permitted sensor range at the azimuth. Radar reports whose range exceeds the sensor maximum range shall be discarded.

3.4.6.4 ATCRBS target-to-track correlation.

Note: Computer sizing for ATCRBS target-to-track correlation shall be based upon an ATCRBS population that is composed of 50 percent discrete code and 50 percent non-discrete code aircraft. Special case execution shall be as follows:

Velocity reasonableness:	10% of reports
Quality score:	10% of reports
1-track x 2-reports:	4% of the reports
2-tracks x 1-report:	2% of the reports
2-tracks x 2-reports:	4% of the reports
Deviation score:	1% of the reports
m x n correlation:	1% of the reports
(m>2 or n>2)	

3.4.6.4.1 Purpose.- The purpose is to correlate ATCRBS target reports received from ATCRBS preprocessing (3.4.6.3.4), with existing ATCRBS tracks in the surveillance file (3.4.6.2), and convert false tracks to real tracks.

3.4.6.4.2 Inputs.- The inputs shall be ATCRBS target reports from ATCRBS preprocessing, plus existing ATCRBS tracks residing in the surveillance file.

3.4.6.4.2.1 Target report inputs.- The relevant target report items used in ATCRBS target-to-track correlation shall be:

- (a) Measured range.
- (b) Measured azimuth.
- (c) ATCRBS 4096 and mode 2 code words.
- (d) ATCRBS mode C altitude word.
- (e) 4096 and mode 2 code confidence words.
- (f) Mode C altitude confidence word.
- (g) Altitude type setting.
- (h) Number of mode A replies used to generate the report.
- (i) Number of mode C replies used to generate the report.
- (j) Number of mode 2 replies used to generate the report.

3.4.6.4.2.2 Surveillance file inputs.- The relevant items from existing ATCRBS tracks in the surveillance file shall be:

- (a) Predicted range - This is the expected range of the track.
- (b) Predicted azimuth - This is the expected azimuth of the track.
- (c) ATCRBS 4096 code word - This is the 4096 code of the track.
- (d) ATCRBS mode C altitude word - This is the mode C altitude of the track.
- (e) ATCRBS 4096 code confidence word - This specifies which bits in the 4096 code are high confidence (3.4.5.3.3).
- (f) ATCRBS mode C altitude confidence word - This specifies which bits in the altitude are high confidence.
- (g) Altitude type setting - This specifies the type of track altitude as defined in Table 3.4.6-2.
- (h) Track firmness, f, as defined in 3.4.6.10.4.1.
- (i) Track history firmness, g, as defined in 3.4.6.10.4.1.

3.4.6.4.3 Outputs.- The output shall be pairings of target reports and tracks, plus leftover unpaired target reports and tracks. The pairings shall be used in ATCRBS track update (3.4.6.6), and the leftover unpaired reports shall be used in ATCRBS track initiation (3.4.6.5). The pairings shall be placed in a table referred to herein as the target-to-track correlation table. This table shall contain the report, or a pointer to the report, that correlates with each track. If there is no such report, then the table shall contain a null value, or a null pointer. The leftover unpaired reports shall be placed in a table referred to herein as the uncorrelated reports table.

3.4.6.4.4 Definitions.- The following definitions apply:

$\Delta\theta_{ij}$	The magnitude of the azimuth difference between the i th report and the j th track.
$\Delta\rho_{ij}$	The magnitude of the range difference between the i th report and the j th track.
Δh_{ij}	The magnitude of the height difference between the i th report and the j th track as defined in para. 3.4.6.4.4.1.
ΔC_{ij}	The magnitude of the code difference between the i th report and the j th track as defined below: <ul style="list-style-type: none"> (a) If C_i and C_j agree in all common high confidence bits, and at least 1 such bit exists, then $\Delta C_{ij} = 0$. (b) If C_i and C_j contain no common high confidence bits, or if C_i or C_j or both are non-existent, then $\Delta C_{ij} = 1/2 \Delta C_{max}$. (c) If C_i and C_j differ in from one to ΔC_{err} common high confidence bits in any positions, then $\Delta C_{ij} = \Delta C_{max}$. (d) If C_i and C_j differ in from $1 + \Delta C_{err}$ to 12 common high confidence bits in any positions, then $\Delta C_{ij} = 2\Delta C_{max}$.
$\Delta\rho_{max}^{jz}$	Range zone boundaries in R_u (as specified in 3.4.6.4.6.1) for track j
$\Delta\theta_{max}^{jz}$	Azimuth zone boundaries in A_u (as specified in 3.4.6.4.6.1) for track j
Δh_{max}	10 (5-15, 1) 100's of feet
ΔC_{max}	10.
Discrete 4096 code	A 4096 report code or track code having all bits high confidence, having at least one non-zero-bit in positions C_4 to D_1 , and if a report, the code swap bit must not be set.
$\Delta\rho_{reas}$	Reasonableness test range window 400 (200-800, 100) R_u .
$\Delta\theta_{reas}$	Reasonableness test azimuth window 200 (50-1000, 50) A_u .
ρ_{reas}	Reasonableness test range cut off 1000 (400-1600, 100) R_u .
Δh_{err}	Number of permissible altitude bit errors 1 (0-8, 1).
ΔC_{err}	Number of permissible code bit errors 1 (0-8, 1).
$P_{h1} = 0.9$	<u>Note:</u> P_{h1} and P_{h2} are probability parameters chosen to give proper priority levels to possible altitude match pairings.
$P_{h2} = 0.8$	

3.4.6.4.4.1 Calculation of Δh_{ij} . Variable h_{ij} , representing the difference in flight levels of the j th track and the i th report, shall be set in accordance with Table 3.4.6-3. Report and track altitude types given correspond to those defined in Table 3.4.6-2. The "had been X" track altitude type categories permit avoiding the rejection of associations on the basis of no longer valid altitude information.

TABLE 3.4.6-3

ALTITUDE ASSOCIATION CASES

Values of Δh_{ij}

Report Track		(1) No replies	(2) Garbled brackets	(3) Clear brackets	(4) Garbled level	(5) Clear level
(1)	No replies	0	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$
(2)	Garbled brackets	$Ph1 * \Delta h_{max}$	0	0	Compare bits or $Ph2 * \Delta h_{max}$	compare bits or $Ph2 * \Delta h_{max}$
(3)	Clear brackets	$Ph1 * \Delta h_{max}$	0	0	$Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$
(4)	Garbled level	$Ph1 * \Delta h_{max}$	Compare bits or $Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$	Compare bits	Compare bits
(5)	Clear level	$Ph1 * \Delta h_{max}$	Compare bits or $Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$	Compare bits	diff or compare bits
(6)	"Had been" no replies	0	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$	$Ph1 * \Delta h_{max}$
(7)	"Had been" brackets	$Ph1 * \Delta h_{max}$	0	0	$Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$
(8)	"Had been" garbled level	$Ph1 * \Delta h_{max}$	Compare bits or $Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$	Compare bits or Δh_{max}	Compare bits or Δh_{max}
(9)	"Had been" clear level	$Ph1 * \Delta h_{max}$	Compare bits or $Ph2 * \Delta h_{max}$	$Ph2 * \Delta h_{max}$	Compare bits or Δh_{max}	diff or compare bits or Δh_{max}

Δh_{ij} computation or value is given

or means choose best score

The symbol $|diff|$ means the absolute difference in 100 foot flight levels between the altitudes, divided by S , the number of scans since the track altitude was updated.

In those cases where "compare bits" is indicated, Δh_{ij} is to be calculated as follows:

$$\Delta h_{ij} = [5 + 5 * \max\{0, d_{high} - \Delta h_{err}\}] / S$$

where

d_{high} = number of common high confidence bit differences in altitude code digits $D_4D_2D_1A_4A_2A_1B_4B_2B_1$ taken as a group.

This space unused intentionally.

3.4.6.4.5 Unique code correlation.

3.4.6.4.5.1 Unique code track file.- Two track files shall be maintained for ATCRBS tracks. The unique code track file shall contain all discrete code tracks which are unique. If two or more tracks exist with the same discrete code, they all shall be kept in the general track file. All tracks with nondiscrete codes shall be kept in the general track file.

3.4.6.4.5.2 Correlation of discrete code tracks.-

The correlation of discrete 4096 code tracks residing in the unique code track file (but not those residing in the general track file) shall be performed as follows. First, if one and only one report both has a discrete 4096 code that matches that of the unique code track and passes the reasonableness test defined in (a), (b), and (c) below, then the track and matching report shall be immediately correlated, and neither shall be subject to the association procedures of 3.4.6.4.6.

Reasonableness Test:

The reasonableness test shall be satisfied if:

- (a) $\Delta \rho_{ij} \leq \Delta \rho_{reas.}$
- (b) $\Delta \theta_{ij} \leq \Delta \theta_{reas.}$ when $\rho_i \geq \rho_{reas.}$, otherwise any $\Delta \theta_{ij}$ is acceptable.
- (c) $\Delta h_{ij} \leq \Delta h_{max}$ if report is not a code swap candidate
 $\Delta h_{ij} < 1/2 \Delta h_{max}$ if report is a code swap candidate

Otherwise, if two or more reports have discrete 4096 codes that match that of the unique code track and pass the above reasonableness test, then track correlation shall be performed with one of this set of matching reports, using the selection procedure defined in (d) and (e) below. All other unselected reports shall be marked as false.

Selection Procedure for unique-code tracks:

- (d) If no matching report has an elevation angle that exceeds an elevation limit parameter (nominally 30 degrees), the report with the shortest range shall be immediately correlated with the unique code track. Neither the track nor the set of matching reports shall be subject to the association procedures of 3.4.6.4.6.
- (e) If one or more matching reports have elevation angles that exceed the elevation limit, then selection of the matching report to be correlated to the unique code track shall be made using the association procedures of 3.4.6.4.6. In applying these association procedures, no other non-matching report may be associated to the unique code track, and no other track may be associated to any of the matching reports.

All unique code tracks not receiving any matching report correlations, and all discrete code reports not matching any unique code track, shall be retained and be subject to the association procedures of 3.4.6.4.6.

3.4.6.4.6 Report-to-track association.

3.4.6.4.6.1 Calculation of association zones.- Three association zone boundaries shall be calculated for each track (except for tracks that were correlated in 3.4.6.4.5.2). The azimuth boundary ($\Delta\theta_{\max}$) of each of the three zones shall not exceed N sectors.

$$(a) \Delta\rho^{j1}_{\max} = \sigma_{\rho} * (1 + 2f)$$

$$\Delta\theta^{j1}_{\max} = \max(\sigma_{\theta}, \frac{\sigma_{\rho}}{\rho_{\text{pred}}} * \frac{2^{13}}{\pi}) * (1 + 2f)$$

$$(b) \Delta\rho^{j2}_{\max} = \Delta\rho^{j1}_{\max} + .0421 * a_g * 192 * \left\{ \frac{T}{4} \right\}^2 * (f^2 + f_g)$$

$$\Delta\theta^{j2}_{\max} = \Delta\theta^{j1}_{\max} + \frac{.0421 * a_g * 192}{\rho_{\text{pred}} * (\pi/2^{13})} * \left\{ \frac{T}{4} \right\}^2 * (f^2 + f_g)$$

This page intentionally unused

(c) $\Delta \rho j^3_{\max} = n * \Delta \rho j^2_{\max}$, but no greater than

$$\max\{100 * T, \Delta \rho j^2_{\max}\}$$

$\Delta \theta j^3_{\max} = n * \Delta \theta j^2_{\max}$, but no greater than

$$\max\{100 * T, \frac{100}{\rho_{\text{pred}}} * \frac{2^{13}}{\pi} * T, \Delta \theta j^2_{\max}\}$$

(d) Parameters to be used in (a), (b) and (c) are:

a_g g's of turn = 1 (0.5 - 2.0, 0.1)
 f firmness per para. 3.4.6.10.4.1
 g history firmness per para. 3.4.6.10.4.1
 n 4(2-6,1) (Note: n is empirical)
 σ_ρ 3-sigma range accuracy = 8(4-16,1) Ru
 σ_θ 3-sigma angle accuracy = 8(4-16,1) Au
 T antenna scan time, seconds
 N maximum azimuth of correlation box = 4(2 - 4,1) sectors

3.4.6.4.6.2 Associations.- Report to track associations shall be made as defined below and summarized in Tables 3.4.6-4 (a) and (b).

3.4.6.4.6.2.1 Permanent associations.- This step shall be to identify as permanent associations, of type I or II, all report i to track j pairings that satisfy one of the following sets of conditions:

- I. (a) $\Delta \rho_{ij} < \Delta \rho j^2_{\max}$ and
 (b) $\Delta \theta_{ij} < \Delta \theta j^2_{\max}$ and
 (c) $\Delta h_{ij} < 1/2 \Delta h_{\max}$ and
 (d) $\Delta C_{ij} < 1/2 \Delta C_{\max}$

- II. Case 1:
 (a) $\Delta \rho_{ij} < \Delta \rho j^2_{\max}$ and
 (b) $\Delta \theta_{ij} < \Delta \theta j^2_{\max}$ and
 (c) $1/2 \Delta h_{\max} < \Delta h_{ij} < \Delta h_{\max}$ and
 (d) $\Delta C_{ij} > 1/2 \Delta C_{\max}$

- Case 2:
 (a) $\Delta \rho j^2_{\max} < \Delta \rho_{ij} < \Delta \rho j^3_{\max}$ or
 (b) $\Delta \theta j^2_{\max} < \Delta \theta_{ij} < \Delta \theta j^3_{\max}$ and
 (c) $\Delta h_{ij} < 1/2 \Delta h_{\max}$ and
 (d) $\Delta C_{ij} < 1/2 \Delta C_{\max}$ and
 (e) track j is real and mature and report i has 2 or more replies

For each such association, the zone that the report i lies in, relative to the track j , shall be determined as defined below.

TABLE 3.4.6-4(a)ASSOCIATION TABLE FOR ZONES 1 and 2

<u>Report Code Conditions</u>	<u>Report Altitude Conditions</u>		
	$\Delta h_{ij} < 1/2\Delta h_{\max}$	$1/2\Delta h_{\max} \leq \Delta h_{ij} \leq \Delta h_{\max}$	$\Delta h_{ij} > \Delta h_{\max}$
$\Delta C_{ij} < 1/2\Delta C_{\max}$	Permanent Association (I)	Tentative Association (alt code)	Tentative Association (alt code)
$1/2\Delta C_{\max} \leq \Delta C_{ij} \leq \Delta C_{\max}$	Tentative Association (alt code)	Permanent Association (II)	No Association
$\Delta C_{ij} > \Delta C_{\max}$	Tentative Association (alt code)	Permanent Association (II)	No Association

TABLE 3.4.6-4(b)ASSOCIATION TABLE FOR ZONE 3

<u>Report Code Conditions</u>	<u>Report Altitude Conditions</u>		
	$\Delta h_{ij} < 1/2\Delta h_{\max}$	$1/2\Delta h_{\max} \leq \Delta h_{ij} \leq \Delta h_{\max}$	$\Delta h_{ij} > \Delta h_{\max}$
$\Delta C_{ij} < 1/2\Delta C_{\max}$	Permanent Association* (II)	No Association	No Association
$1/2\Delta C_{\max} \leq \Delta C_{ij} \leq \Delta C_{\max}$	No Association	No Association	No Association
$\Delta C_{ij} > \Delta C_{\max}$	No Association	No Association	No Association

*If the track is false, or not yet mature, or the target report has only one reply, designate this square as "No Association".

The report is in zone 1 if:

$$0 < \Delta\rho_{ij} < \Delta\rho_{ij}^1_{\max}$$

and

$$0 < \Delta\theta_{ij} < \Delta\theta_{ij}^1_{\max}$$

The report is in zone 2 if:

$$\Delta\rho_{ij} < \Delta\rho_{ij}^2_{\max}$$

and

$$\Delta\theta_{ij} < \Delta\theta_{ij}^2_{\max}$$

and the report is not in zone 1.

The report is in zone 3 if it is not in zones 1 or 2.

3.4.6.4.6.2.2 Tentative associations.- It is possible that ATCRBS reply correlation (3.4.5.6) will output pairs of target reports that have their 4096 codes mistakenly interchanged. The purpose of making tentative associations is to identify reports that may be members of such pairs. The reports so identified will be used in the report code swapping step as specified in 3.4.6.4.6.3.

The first step shall be to identify as tentative associations of the type (alt code) all report i to track j pairings that satisfy the following conditions:

- (a) $\Delta\rho_{ij} < \Delta\rho_{ij}^2_{\max}$
- (b) $\Delta\theta_{ij} < \Delta\theta_{ij}^2_{\max}$
- (c) $\Delta h_{ij} < 1/2\Delta h_{\max}$
- (d) $\Delta C_{ij} > 1/2\Delta C_{\max}$

The next step shall be to identify as tentative associations of the type (alt code) all report i to j pairings that satisfy the following conditions:

- (a) $\Delta\rho_{ij} < \Delta\rho_{ij}^2_{\max}$
- (b) $\Delta\theta_{ij} < \Delta\theta_{ij}^2_{\max}$
- (c) $\Delta h_{ij} > 1/2\Delta h_{\max}$
- (d) $\Delta C_{ij} < 1/2\Delta C_{\max}$

3.4.6.4.6.3 Report 4096 and mode 2 code swapping.

3.4.6.4.6.3.1 Report 4096 code swapping.- The 4096 report code, code confidence and number of replies of a type (alt code) tentative association shall be swapped with the 4096 report code, code confidence and number of replies of a type (alt code) whenever the following conditions are satisfied: #

- (a) Both reports have their potential code swap bits set to 1.
- (b) Neither report has a type I permanent association with a track (3.4.6.4.6.2.1).
- (c) Both tentative associations are to the same track.
- (d) That track has no type I permanent association with any report.
- (e) The magnitude of the range difference between the reports is less than $\Delta\rho$ defined in 3.4.5.6.5.
- (f) The magnitude of the azimuth difference between the reports is less than $\Delta\psi$ defined in 3.4.5.6.5.

3.4.6.4.6.3.2 Mode 2 code swapping.- The following tasks shall be performed for every 4096 code swap made in 3.4.6.4.6.3.1 above:

- (a) If in the pair of reports only one had a mode 2 code having all high confidence bits, then that mode 2 code and its confidence word shall be assigned to the report having altitude and 4096 code agreement with the track, and the other report shall have its mode 2 code set to all bits low confidence.
- (b) If in the pair of reports both had mode 2 codes having all high confidence bits, and the mode 2 codes are different, or if neither report has a mode 2 code having all bits high confidence, then the mode 2 code confidence words of both reports shall be set to all bits low confidence.

3.4.6.4.6.4 Resolution of tentative associations.- After all possible code swapping has been effected, all tentative associations shall be converted to permanent associations or no associations according to the following rules, where the association zone is determined as in 3.4.6.4.6.2.1:

- (a) if $\Delta h_{ij} < \Delta h_{\max}$ and the report is in zone 1, the association shall become permanent type I;
- (b) if $\Delta h_{ij} < \Delta h_{\max}$ and the report is in zone 2, the association shall become permanent type II;
- (c) if $\Delta h_{ij} > \Delta h_{\max}$, the association shall become no association.

3.4.6.4.6.5 Resolution of type II permanent associations.- After all tentative associations have been resolved, all type II permanent associations that satisfy the velocity reasonableness test specified in 3.4.6.4.6.6 shall be converted to type I permanent associations. All type II permanent associations that fail this test shall be converted to no associations.

3.4.6.4.6.6 Velocity reasonableness test.- A target report i shall be said to have passed the velocity reasonableness test with respect to track j if the two tests specified in 3.4.6.4.6.6.2 and 3.4.6.4.6.6.3 are satisfied.

3.4.6.4.6.6.1 Definitions. - The following definitions apply:

Note: Regions 1, 2, and 3, and the methods of calculating ρ_{pred} and θ_{pred} are defined in para. 3.4.6.10.4.2.

v The vector from the last known track position to the target report position, calculated as follows:

(a) if track j is in regions 1 or 2:

$$v_{\rho} = \rho_1 - \rho_{jpred} + f * \dot{\rho}_{jpred}$$

$$v_{\theta} = \{\theta_1 - \theta_{jpred} + f * \dot{\theta}_{jpred}\} * \rho_{jpred} * \pi/2^{1/3}$$

$$\underline{v} = (v_{\rho}, v_{\theta})$$

(b) if track j is in region 3:

$$v_x = (\rho_1^2 - h_j^2)^{1/2} \sin \theta_1 - x_{jpred} + f * \dot{x}_{jpred}$$

$$v_y = (\rho_1^2 - h_j^2)^{1/2} \cos \theta_1 - y_{jpred} + f * \dot{y}_{jpred}$$

$$\underline{v} = (v_x, v_y)$$

where predicted track position and rate components for track j,

x_{jpred} , y_{jpred} , \dot{x}_{jpred} and \dot{y}_{jpred} , are maintained in the surveillance file (3.4.6.2).

w The vector from the last known track position to the predicted track position, calculated as follows:

(a) if track j is in regions 1 or 2:

$$w_{\rho} = f * \dot{\rho}_{jpred}$$

$$w_{\theta} = f * \dot{\theta}_{jpred} * \rho_{jgnd} * \pi/2^{1/3}$$

$$\underline{w} = (w_{\rho}, w_{\theta})$$

(b) if track j is in region 3:

$$w_x = f * \dot{x}_{jpred}$$

$$w_y = f * \dot{y}_{jpred}$$

$$\underline{w} = (w_x, w_y)$$

where \dot{x}_{jpred} and \dot{y}_{jpred} are as defined above.

f The track firmness as defined in 3.4.6.10.4.1.

3.4.6.4.6.6.2 Test one.- This test is satisfied if any of the following three conditions are met:

- (a) $\dot{\rho}_{jpred} < e_{\rho}$ or
- (b) $\dot{\theta}_{jpred} < e_{\theta} * \rho_{jgnd}$ or
- (c) $\frac{||\underline{w}|| * ||\underline{v}||}{||\underline{w}|| * ||\underline{v}||} \geq - (f-1) * \rho_1$

where

$$e_{\rho} = 20(5-100, 5)$$

Note: e_{ρ} and e_{θ} are based on Mode S sensor ρ and θ error characteristics.

$$e_{\theta} = 10(5-50, 5) * \pi/2^{13}$$

$$\rho_{jgnd} = (\rho_{jpred}^2 - \hat{h}_j^2)^{1/2}$$

ρ_{jpred} and \hat{h}_j (i.e., $2*1.627*h_j - h_s$) where h_s = height of the sensor antenna above sea level in Ru are obtained from the track file.

$$\rho_1 = 0.25 (0.1-0.5, 0.05).$$

3.4.6.4.6.6.3 Test two.- This test is satisfied if the following condition met:

$$\frac{||\underline{v}||}{||\underline{w} + \underline{e}||} \leq \rho_2$$

$$\rho_2 = 1.25 (1.0 - 2.0, 0.05)$$

$$\underline{e} = (e_{\rho}, e_{\theta} * \rho_{jgnd}) \text{ if track is in regions 1 or 2}$$

$$= (e_{\rho}, e_{\rho}) \text{ if track is in region 3.}$$

3.4.6.4.7 Single-track, single-report correlation.- This step shall be to identify all cases where a track associates with one and only one report and that report associates only with the given track. The track and report shall be correlated and entered into the target-to-track correlation file. This report and the track shall not enter into 3.4.6.4.8, 3.4.6.4.9, or 3.4.6.4.10, below.

3.4.6.4.8 Single-track, multiple-report correlation.- This step shall be to identify all cases where a track associates with more than one report, and each of these reports associates only with the track under consideration. The report with the lowest quality score shall be correlated with the track. If the low quality score (defined in 3.4.6.4.11) appears for more than one association, then the deviation score (defined in 3.4.6.4.12) shall be computed for each such association. The report with the lowest deviation score shall be correlated with the track. This track and all its associated reports shall not enter in 3.4.6.4.9, or 3.4.6.4.10, below.

3.4.6.4.9 Multiple-track, single-report correlation.- This step shall be to identify all cases where a report associates with more than one track, and each of these tracks associates only with the report under consideration. The track with the lowest quality score (defined in 3.4.6.4.11) shall be correlated with the report. If the low quality score appears for more than one association, then the deviation score (defined in 3.4.6.4.12) shall be computed for each such association. The track with the lowest deviation score shall be correlated with the report. This report and all its associated tracks shall not enter into 3.4.6.4.10 below.

3.4.6.4.10 Multiple-track, multiple-report ("many-on-many") correlation.

3.4.6.4.10.1 Formation of closed set of reports and tracks.- This step shall be to identify all cases where:

(a) There are two or more reports associated with a track (for example, track A).

(b) One or more of the reports in (a) above associates with one or more tracks in addition to track A.

In these cases, a closed set of tracks and reports, none of which associates with a track or report not in the set, shall be determined, whenever possible. In those cases when this is not possible, correlation for the earliest track in the set shall be completed by the time the track is N sectors old, where N is given in 3.4.6.4.6.1, by employing the subset of reports and tracks known by that time.

3.4.6.4.10.2 Formation of resolution matrix.- A matrix, referred to herein as the resolution matrix, shall be formed. It shall have one row for each report in the set identified in 3.4.6.4.10.1 and one column for each track identified in 3.4.6.4.10.1. The matrix entry for a report and track shall be the quality score defined in 3.4.6.4.11, if the report and track associate. If not, the octal value 50000000 shall be used. Figure 3.4.6-3 shows an example of this matrix.

If there are fewer reports (rows) than tracks (columns), 3.4.6.4.10.3 shall be performed. If there are fewer (or equal) tracks than reports, 3.4.6.4.10.4 shall be performed.

3.4.6.4.10.3 Fewer reports than tracks.- A "quality score-difference" shall be computed for each report. The quality score-difference shall be the magnitude of the difference between the two smallest column entries in the report row. In fig. 3.4.6-3 these values would be:

- (a) for r_1 : 00001000
- (b) for r_2 : 37770000
- (c) for r_3 : 00007000

		<u>Tracks</u>			
		t_a	t_b	t_c	t_d
<u>Reports</u>	r_1	00001010	40000010	50000000	00000010
	r_2	00011010	50000000	40001010	50000000
	r_3	40000010	00001010	40000010	00010010

All Entries are Report-to-Track Quality Scores in Octal

Figure 3.4.6-3 Example of a Resolution Matrix

A correlation shall be attempted for the report having the largest such score-difference. If the largest quality score-difference appears for more than one report, then the deviation scores (defined in 3.4.6.4.12) shall be computed for the associations involved in those largest quality score-differences. These deviation scores shall be added to the quality scores and the new scores shall be differenced and used to identify the report with the largest quality-deviation score-difference. The so-identified report shall be correlated with the associating track having the smallest quality score, if that smallest quality score is less than 50000000. If the smallest quality score appears for more than one track, then the deviation score shall be computed for those tracks, unless the deviation score has already been computed. The report shall be correlated with the track having the smallest quality-deviation score. The report shall be considered uncorrelated if the smallest score is greater than or equal to 50000000. In the example, report r_2 would be correlated with track t_a . After making the first correlation the matrix shall be reduced by deleting the row corresponding to the report and the column corresponding to the track. The process of computing score-differences and attempting correlations shall be repeated until all possible correlations are made.

3.4.6.4.10.4 Fewer (or equal) tracks than reports.- The same process as 3.4.6.4.10.3 shall be performed except that the roles of tracks and reports shall be reversed.

3.4.6.4.11 Computation of the quality score.- The quality score shall occupy the five most significant digits of an eight-digit (octal) number. The three least significant digits are defined in 3.4.6.4.12. The rules for computing the quality score for a target and track are defined below.

<u>Digit</u>	<u>Decision Item</u>	<u>Value</u>
7	Code agreement and zone	
(most significant)	Let: code mean $\Delta C_{ij} < \Delta C_{\max}$	
	and code mean $\Delta C_{ij} > \Delta C_{\max}$	
	code and zone 1	0
	code and zone 2	1
	code and zone 1	2
	code and zone 2	3
	code and zone 3	4
6	Number of replies in report	
	3 or more	0
	2 of the same mode	0
	2 of different mode	1
	1 reply	2

Digit	Decision Item	Value
5	Code agreement	
	Let: code and $\overline{\text{code}}$ be as in digit 7	
	Let: ahc = the report has all code bits high confidence	
	$\overline{\text{ahc}}$ = at least one low confidence code bit	
	code and $\Delta C_{ij} < \Delta C_{\max}$ and ahc	0
	code and $\Delta C_{ij} < \Delta C_{\max}$ and $\overline{\text{ahc}}$, but at least one bit high confidence	1
	report code unknown	2
	report code has all bits low confidence	2
	code and $\Delta C_{ij} = \Delta C_{\max}$	3
	$\overline{\text{code}}$ and $\overline{\text{ahc}}$ and track code transition counter is not equal to zero	4
	$\overline{\text{code}}$ and ahc and track code transition counter is not equal to zero	5
	$\overline{\text{code}}$ and $\overline{\text{ahc}}$ and track code transition counter is equal to zero	6
	$\overline{\text{code}}$ and ahc and track code transition counter is equal to zero	7
4	Altitude agreement	
	$\Delta h_{ij} < 500$ feet	0
	$\Delta h_{ij} = 600$ feet	1
	$\Delta h_{ij} = 700$ feet	2
	$\Delta h_{ij} = 800$ feet	3
	$\Delta h_{ij} = 900$ feet	4
	$\Delta h_{ij} = 1000$ feet	5
	otherwise	6

<u>Digit</u>	<u>Decision Item</u>	<u>Value</u>
3	Track	
	Let: e = mature track (See 3.4.6.6.8)	
	\bar{e} = not mature	
	e and track range $> R_{min}$	0
	e and track range $< R_{min}$	1
	\bar{e} and track range $> R_{min}$	2
	\bar{e} and track range $< R_{min}$	3

2,1,0

Deviation score, D, as defined in 3.4.6.4.12.
 Note that the deviation score bits shall only
 be calculated when required as specified in
 3.4.6.4.8, 3.4.6.4.9, or 3.4.6.4.10.

3.4.6.4.12 Computation of the deviation score, D.- The deviation score shall be calculated and combined with the quality score when required, as specified in 3.4.6.4.8, -.9, or -.10.

Note: The purpose of the deviation score is to break quality score ties, such as those which occur if two aircraft without encoding altimeters both report a code of 1200. The deviation score takes into account geometric differences between track and report positions and the fact that changes in aircraft speed from scan to scan are unlikely, most changes in aircraft velocity being caused by turns.

3.4.6.4.12.1 Definitions.-

ρ_{smooth}	radial velocity of a track in Ru per scan
θ_{smooth}	azimuth velocity of a track in Au per scan
ρ_{pred}	track prediction in range for this scan
θ_{pred}	track prediction in azimuth for this scan
$\Delta\rho$	(target report range - ρ_{pred})
$\Delta\theta$	(target report azimuth - θ_{pred})
ω	turn magnitude, radians (3.4.6.4.12.3)
a	$\frac{1 - \cos\omega}{\omega}$
b	$1 - \frac{\sin\omega}{\omega}$

\vec{d} difference in positions of target report and track prediction expressed as a vector with components d_p and d_θ

d_p radial component of \vec{d}

d_θ tangential component of \vec{d}

\vec{t} a vector in the direction of the turning locus having cross-track and along-track components t_c and t_l

f_1 penalty factor for absolute distance between target and track

f_2 penalty factor rating the direction of the target/track deviation

σ_p 3-sigma range measurement error parameter (3.4.6.4.12.3)

σ_θ 3-sigma azimuth measurement error parameter (3.4.6.4.12.3)

D the deviation score

3.4.6.4.12.2 Computation.-

(a) \vec{p}_{pred} in Region 1 or Region 2 (3.4.6.10.4.2):

$$\vec{d} = (d_p, d_\theta) \quad \begin{aligned} d_p &= \Delta p \\ d_\theta &= \rho \Delta \theta * \pi/2^{1/3} \end{aligned}$$

$$\vec{t} = \vec{t}_c - \vec{t}_l$$

$$\vec{t}_c = (t_{cp}, t_{c\theta}) \quad \begin{aligned} t_{cp} &= -a\dot{\theta}_{smooth} * \pi/2^{1/3} \\ t_{c\theta} &= a\dot{\theta}_{smooth} \end{aligned}$$

$$\vec{t}_l = (t_{lp}, t_{l\theta}) \quad \begin{aligned} t_{lp} &= b\dot{\theta}_{smooth} \\ t_{l\theta} &= b\dot{\theta}_{smooth} * \pi/2^{1/3} \end{aligned}$$

$$D = f_1 * f_2$$

where:

$$f_1 = \frac{|\Delta p|}{\sigma_p} + \frac{|\rho \Delta \theta|}{\rho \sigma_\theta}$$

$$f_2 = \frac{C_{\text{perp}}}{C_{\text{par}}} \quad \text{constrained to: } 0.5 \leq f_2 \leq 2.0$$

$$\text{where: } C_{\text{par}} = \frac{C_{\text{par}}}{|d \cdot t|}$$

$$C_{\text{perp}} = (|d|^2 - C_{\text{par}}^2)^{1/2}$$

The deviation score, D, shall be quantized to 25ths and added to the quality score when required (3.4.6.4.8, -.9 and -.10).

(b) ρ_{pred} in Region 3 (3.4.6.10.4.2):

$$\vec{d} = (d_x, d_y) \quad d_x = \Delta x$$

$$d_y = \Delta y$$

$$\vec{t} = \vec{t}_c - \vec{t}_1$$

$$\vec{t}_c = (t_{cx}, t_{cy})$$

$$t_{cx} = -ay$$

$$t_{cy} = ax$$

$$\vec{t}_1 = (t_{1x}, t_{1y})$$

$$t_{1x} = bx$$

$$t_{1y} = by$$

$$D = f_1 \times f_2$$

$$\text{where: } f_1 = \frac{|\Delta x|}{\sigma_p} + \frac{|\Delta y|}{\sigma_p}$$

$$f_2 = \frac{C_{\text{perp}}}{C_{\text{par}}}$$

$$\text{where: } C_{\text{par}} = \frac{C_{\text{par}}}{|d \cdot t|}$$

$$C_{\text{perp}} = (|d|^2 - C_{\text{par}}^2)^{1/2}$$

Here too, the deviation score, D, shall be quantized to 25ths and added to the quality score when required.

3.4.6.4.12.3 Parameters.-

$$\begin{aligned}\omega &= 0.05 \text{ (0.025 - 0.075, 0.005) radians/second * T scan} \\ \sigma_p &= 3 \text{ (2 - 4, 1) Ru} \\ \sigma_\theta &= 7 \text{ (5 - 10, 2) Au}\end{aligned}$$

3.4.6.4.13 One-hit report rejection.- Reports not correlating to an existing track shall be rejected if they were generated from only one reply.

3.4.6.4.14 ATCRBS 4096 code validation.- When a target report is correlated with an existing track, its 4096 code may or may not match the code in the track file. If the codes do not agree the match was based on the geometric quantities range, azimuth, and altitude. The following cases shall be recognized and the target report code modified as indicated prior to surveillance data dissemination:

(a) The target report has all high confidence bits and they match all of the high confidence bits in the track file code. Send the report unchanged.

(b) The target report has some low confidence bits, but all high confidence bits match the high confidence bits in the track file code. Replace the report code by the track code.

(c) The target report has some high confidence bits in its code that do not match the high confidence bits in the track file code. Send the report unchanged, but set the code-in-transition bit.

3.4.6.4.15 ATCRBS Mode C altitude code validation.- When a target report is correlated with an existing track, its mode C altitude code may or may not be represented in flight levels via the decoding action in 3.4.6.3.4(c). In either case, this code may or may not match the code in the track file. The following cases shall be recognized and the target report fields modified as indicated prior to surveillance data dissemination:

(a) The target report altitude has been decoded and the report and track altitudes satisfy: $\Delta h_{1j} \leq \Delta h_{\max}$ (calculation in 3.4.6.4.4.1). Send the report unchanged.

(b) The target report altitude has been decoded and the report and track altitudes disagree: $\Delta h_{1j} > \Delta h_{\max}$. Convert the report altitude field back to the original bit values, set the altitude confidence field to all bits low confidence, and change the type setting to "1", garbled flight level.

(c) The following conditions apply:

- (i) the target report altitude is not decoded as it is type "1", garbled flight level
- (ii) the track altitude is type "0", presently decoded in flight levels
- (iii) if the target altitude was decoded as in 3.4.6.3.4(c), assuming all bits were high confidence, and compared to the track's altitude,

$$\Delta h_{1j} = \frac{|\text{target altitude} - \text{track altitude}|}{S} < \Delta h_{\text{conv}}$$

would be found to apply, where S is defined in 3.4.6.4.4.1 and $\Delta h_{\text{conv}} = 3 (1-5,1)$.

Convert the report altitude field into flight level form, set the altitude confidence field to all bits high confidence, and change the type setting to "0".

(d) Conditions (i) and (ii) of (c) apply, but $\Delta h_{1j} > \Delta h_{\text{conv}}$. Send the report unchanged.

(e) All other cases, send the report unchanged.

3.4.6.4.16 False-to-real track conversion.

3.4.6.4.16.1 Definition of track types.-

- a. Possibly False - Type 1: A track is defined as possibly false type 1 if the report stream corresponding to the track (including the two uncorrelated reports used to initiate it) consists only of reports labeled possibly false in accordance with 3.4 6.13.4
- b. Possibly False - Type 2: A track is defined as possibly False-Type 2 if the report stream corresponding to the track consists of one report labeled false and all the rest are labeled possibly false.
- c. False Track: A track is defined as false if the report stream corresponding to the track consists of two or more reports labeled false and all the rest are labeled possibly false.
- d. Real Track: A track is defined as real if the report stream corresponding to the track consists of any real reports.

3.4.6.4.16.2 Report and Track Flagging.- The zone test specified in 3.4.6.13.4 shall be performed for all target reports that correlate to false or possibly false tracks. If the zone test indicates that the report is real, the track and report shall be flagged as real. If the zone test considers the report to be false, then the image test specified in 3.4.6.13.5.1 shall be performed. If the image test indicates that the target report is real, then the report and track shall be flagged as real. If the image test indicates that the report is false, and the track is false or possibly false type 2, then the report and track shall be flagged as false. If the image test indicates that the report is false, and the track is possibly false Type 1, then the report shall be flagged as real and the track converted to possibly false type II. If the image test indicates that the report is possibly false, then the report shall be flagged false if the track is false, or real if the track is possibly false, and the track type left unchanged.

3.4.6.4.17 Correlation confidence bit.- Whenever a target report correlated with a track and it fell within the track's zone one, the correlation confidence bit shall be set in the target report for data dissemination.

3.4.6.5 ATCRBS track initiation.

3.4.6.5.1 Purpose.- The purpose of ATCRBS track initiation is to initiate ATCRBS tracks using uncorrelated reports received from ATCRBS target-to-track correlation (3.4.6.4).

3.4.6.5.2 Inputs.- The inputs shall be target reports provided by ATCRBS target-to-track correlation which did not correlate with existing tracks, plus the uncorrelated ATCRBS reports saved from the previous scan.

The relevant target report items used are:

- (a) Range
- (b) Azimuth
- (c) ATCRBS 4096 code word
- (d) ATCRBS mode C altitude word
- (e) 4096 code confidence word
- (f) Mode C altitude confidence word
- (g) Altitude type setting

3.4.6.5.3 Outputs.- The output shall be newly initiated ATCRBS tracks based on two consecutive-scan target reports. The track shall be entered in the surveillance file (3.4.6.2), and the correlating report shall be output to ATCRBS track update (3.4.6.6).

The newly initiated track fields shall contain the following information:

- (a) Range prediction = range of report from previous scan
- (b) Azimuth prediction = azimuth of report from previous scan
- (c) Range rate = 0

- (d) Azimuth rate = 0
- (e) Last measured range = range of report from previous scan
- (f) Last measured azimuth = azimuth of report from previous scan
- (f) Track firmness = 3.
- (h) Track history firmness = 0
- (i) ATCRBS 4096 code and confidence fields from previous scan report
- (j) Mode C altitude and confidence and altitude type from previous scan report

3.4.6.5.4 Rules of operation.- Uncorrelated ATCRBS reports from the previous scan shall be used as transient tracks to provide the first seven surveillance file inputs to 3.4.6.4.2.2. The following values shall be used for zone boundaries for all transient tracks.

$$\Delta \theta j1_{\max} = \Delta \theta j2_{\max} = 16 \times T \text{ scan, Ru}$$

$$\Delta \theta j3_{\max} = 128 \times T \text{ scan, Ru}$$

$$\Delta \theta j1_{\max} = \Delta \theta j2_{\max} = \frac{16 \times T \text{ scan}}{\rho_{\text{predicted}}} \times \frac{2^{13}}{\pi} \text{ Au}$$

$$\Delta \theta j3_{\max} = \frac{128 \times T \text{ scan}}{\rho_{\text{predicted}}} \times \frac{2^{13}}{\pi} \text{ Au.}$$

Uncorrelated ATCRBS reports from this scan shall be used to provide the target report inputs to 3.4.6.4.2.1.

The ATCRBS target-to-track correlation shall then compute the association functions listed below:

Δh_{ij}	3.4.6.4.4.1
ΔC_{ij}	3.4.6.4.4
Zone of i, j	3.4.6.4.6.1

3.4.6.5.4.1 Track initiation associations.- A potential new track will exist whenever any type of association listed below is identified:

- (a) Type I
 - Zone 1
 - $\Delta h_{ij} \leq 1/2 \Delta h_{\max}$
 - $\Delta C_{ij} < \Delta C_{\max}$
- (b) Type II - not satisfying Type I and
 - Zone 1
 - $\Delta h_{ij} \leq \Delta h_{\max}$
 - $\Delta C_{ij} \leq \Delta C_{\max}$

(c) Type III - not satisfying Types I or II and

Zone 3

$$\Delta h_{ij} < 1/2 \Delta h_{\max}$$

$$\Delta C_{ij} < \Delta C_{\max}$$

All associations of the lowest type for each target report shall be used to start new tracks, but no associations of a type greater than the minimum for each target report shall be used to start a new track.

3.4.6.5.4.2 Linked track sets.- Two or more newly initiated tracks that share a common target report or transient track shall be linked together according to the following rules:

- (a) any target report initiating two or more tracks shall link these tracks into a common set; these tracks shall not be used in (b) below
- (b) any transient track initiating two or more tracks shall link these tracks into a common set.

3.4.6.5.4.3 False track tests.- When a new track is initiated, the transient track and the report shall be given the false target zone and image tests (3.4.6.13). The following actions shall be taken based on the results of these tests:

- (a) If either or both are found to be real, then both the new track and the report shall be declared real.
- (b) If both are found to be possibly false, then the new track shall be declared possibly false Type I and the report shall be declared real.
- (c) If one is found to be possibly false, and the other found to be false, then the new track shall be declared possibly false Type II, and the report shall be declared real.
- (d) If both are found to be false, then both the new track and the report shall be declared false.

3.4.6.5.4.4 Discrete code actions.- If the newly established track has a discrete 4096 code, the following action shall be taken:

- (a) If no other track exists with that discrete code, the new track shall be added to the unique track file (3.4.6.4.5.1).
- (b) If a track with the same discrete code exists in the unique track file, both that track and the newly established one shall be placed in the general track file.

- (c) If two or more tracks already exist with the same discrete code, the new track shall be entered into the general track file.

3.4.6.5.4.5 Uncorrelated report file.- The uncorrelated reports from this scan shall be saved in the last scan uncorrelated file, and all uncorrelated reports (the uncorrelated transient tracks) from the previous scan shall be purged.

If the third option of early dissemination of uncorrelated beacon reports is selected (3.4.6.14.1.3c), then the ATCRBS Track Initiation function shall suitably indicate for dissemination the second report of the association pair forming the track initiation.

3.4.6.5.4.6 Assignment of track numbers (SFN's).- Track numbers (SFN's) shall be assigned initially in sequence from 1 to the largest number available. Thereafter, numbers assigned shall be those of previously dropped tracks - with the least recently used number assigned first.

3.4.6.6 ATCRBS track update.

3.4.6.6.1 Purpose.- The purpose is to update ATCRBS tracks using correlated beacon or radar target reports.

3.4.6.6.2 Inputs.- The inputs shall be correlated beacon or radar target reports plus the track data provided by the surveillance file.

The relevant items needed by ATCRBS track update are:

- (a) Measured range.
- (b) Measured azimuth.
- (c) Correlating track number.

and for a beacon report:

- (d) ATCRBS 4096 code.
- (e) ATCRBS 4096 code confidence word.
- (f) ATCRBS mode C altitude.
- (g) ATCRBS mode C altitude confidence word.
- (h) ATCRBS altitude type setting.

3.4.6.6.3 Outputs.- The output shall be an updated ATCRBS track.

3.4.6.6.4 Rules of operation.- ATCRBS tracks reporting mode C altitude, and for which all altitude bits in the track file are high confidence, shall have their positions updated the same way as Mode S tracks (3.4.6.10.4) except that the calculations in 3.4.6.10.4.3 shall not be performed, $\Delta \rho_{\max}$ and $\Delta \theta_{\max}$ shall be set equal to $\Delta \rho_{\max}^{j2}$ and $\Delta \theta_{\max}^{j2}$ calculated in 3.4.6.4.6.1, and the special rules described in 3.4.6.6.4.1, 3.4.6.6.4.2, and 3.4.6.6.4.3 shall be followed.

of an extended-length-message (ELM) interface for transferring to and reading from an ELM interface test circuit the message contents of Mode S extended-length uplink (Comm-C) and downlink (Comm-D) transmissions, respectively. The CPME shall transmit altitude reports from an internally simulated pressure-altitude encoder (digitizer).

The CPME shall not include interfaces for connection to external SM, ELM, or altitude encoding devices. Built-in interface test capability shall be provided whose performance shall appear to the sensor to be functionally equivalent to that of ordinary Mode S transponder interfaces. However, identifiable interface hardware of the type required for operational Mode S transponders is not required.

80.3.3 Mode S CPME technical characteristics.

80.3.3.1 Reply conditions.

80.3.3.1.1 ATCRBS reply condition.- The CPME shall reply to standard military Mode 2, ATCRBS Mode 3/A, and Mode C interrogations under the conditions prescribed in FAA Order 1010.51A, except during recovery following a Mode S reply. The CPME shall not reply to ATCRBS interrogations under the conditions prescribed in FAA Order 1010.51A for no reply.

80.3.3.1.2 ATCRBS/Mode S All-Call reply conditions.- The CPME shall reply to an ATCRBS/Mode S All-Call (Mode A or Mode C) interrogation, or an ATCRBS-only All-Call interrogation as specified in the Mode S National Standard, except during recovery following a Mode S or ATCRBS reply, or when the conditions of 80.3.3.1.7 specify otherwise. The CPME shall not reply (with either an All-Call, an ATCRBS, or Mode S reply) in response to an ATCRBS/Mode S All-Call interrogation when the interrogation contains a P2 pulse which satisfies the requirements for ATCRBS suppression. The CPME shall not produce a Mode S All-Call reply in response to a CW transmission or a single pulse of long duration whose received amplitude variations do not approximate an All-Call interrogation. The CPME shall not produce a Mode S All-Call reply in response to a P1-P3 pair alone. In order to elicit an All-Call reply, the P1-P3 transmission shall be followed by a distinct P4 pulse, as specified in the Mode S National Standard.

80.3.3.1.3 Mode S reply conditions.- The CPME shall reply (with probability specified below) to valid Mode S interrogations (Mode S-only All-Call, Surveillance, Comm-A or Comm-C) as described in the Mode S National Standard, which are correctly addressed and within specified limits of received signal amplitude, except when the CPME is in a lockout condition or a recovery state from a prior Mode S or ATCRBS reply. The CPME shall not reply to a Mode S interrogation whenever any one or combination of the following conditions occur:

"Continuously correlating tracks" shall be defined as those:

- (1) Which correlated on both the previous two scans.
- (2) Whose last correlating target report fell within the Zone 1 association zone (3.4.6.4.6.1) of the track.

The following action shall be taken upon encountering a continuously correlating track whose current report falls outside of the Zone 1 association box:

- (1) The track shall be smoothed in the offending coordinate(s) only to the limit of the Zone 1 box.
- (2) An entry shall be made in the turning state field of the surveillance file for each coordinate (ρ and/or θ). The entry(s) shall indicate the direction (positive or negative) of the target deviation.
- (3) If the correlating target report again falls outside of the Zone 1 association box, and in the same direction as during the last scan, full smoothing shall be applied.
- (4) Full smoothing shall continue to be applied as long as the reports fall outside of the box in the same direction.
- (5) If the correlating target report falls outside of the Zone 1 association box in the opposite direction as during the last scan, rules 1 and 2 shall be followed.
- (6) Once a report again falls within the track's Zone 1 box, the smoothing rules shall be terminated and normal tracking rules resumed.

3.4.6.6.4.3 Improving boresight azimuth estimate. For correlating target reports not containing a monopulse azimuth, i.e., those whose boresight bit is set in the ATCRBS Target Report Data Block of figure 3.4.5-7, report azimuth shall be modified to θ' measured before smoothing (3.4.6.10.4.1) as follows:

$$\theta'_{\text{measured}} = \frac{\theta_{\text{measured}} + \theta_{\text{pred}}}{2}$$

3.4.6.6.5 Mode C altitude update. Once each scan the altitude and altitude confidence fields of the surveillance file shall be updated as shown in Table 3.4.6-5. The altitude type setting shall then be set to the proper value as shown in Table 3.4.6-2.

If a track correlates with a target report on the current scan, and if the altitude of the report is acceptable (as defined below), the track altitude fields shall be updated by the report altitude information. However, if neither condition is satisfied, the track altitude shall be "coasted". To prevent the information from becoming too old to be of any value, a two-phase timeout procedure shall be utilized.

TABLE 3.4.6-5

ALTITUDE UPDATE CASES

Report Track		(1) No replies	(2) Garbled brackets	(3) Clear brackets	(4) Garbled level	(5) Clear level
(1)	No replies	R	U	U	U	U
(2)	Garbled brackets	U	I	R	U	U
(3)	Clear brackets	U	L	R	U	U
(4)	Garbled level	U	U	U	U	R
(5)	Clear level	U	U	U	U	R
(6)	"Had been" no replies	R	D	D	D	D
(7)	"Had been" brackets	D	D	R	D	D
(8)	"Had been" garbled level	D	D	D	D	R
(9)	"Had been" clear level	D	D	D	D	R

Altitude update actions:

$R - \begin{cases} \text{if } \Delta h_{1j} < 1/2 \Delta h_{\max}, \text{ replace track altitude and confidence} \\ \text{with report altitude and confidence,} \\ \text{and zero counter.} \\ \text{if } \Delta h_{1j} > 1/2 \Delta h_{\max}, \text{ proceed as under U (or D).} \end{cases}$

U - increment counter; if reach parametric value, set track to "had been" category.

D - decrement counter; if reach 0, replace track altitude with report altitude.

I - improve track altitude and confidence by union of high confidence bits.

L - set counter to zero, leave track altitude as is.

An altitude counter, corresponding to each system track, shall be zeroed every time the altitude fields are successfully updated by a new report. If no update is possible, the counter shall be incremented. When its value reaches a parametric number of scans (nominally 3), the altitude confidence field of the track shall be set to indicate all altitude bits low confidence and the altitude type setting of the track shall be set so that the track becomes a member of the proper "had been X" classification. This setting maintains the most recent altitude information known for the track so that potential associations may be scored properly. No association shall be rejected for a track in this state.

If altitude update failures continue after this point, the altitude counter shall be decremented one unit per scan. When the count reaches zero, the track altitude information shall be defined to be useless. Thus, the next time the track correlates, the altitude, altitude confidence, and type setting fields of the report shall be automatically placed in the track file and the entire sequence begun again.

Entries in Table 3.4.6-5 labelled unacceptable ("U" or "D") signify that the altitude counter shall progress in the manner described above. Those labelled replacement ("R") mean that the target report altitude fields shall replace those currently in the track file, and the altitude counter shall be zeroed. Finally, if both the target and track are garbled brackets (Table 3.4.6-5, Item 2), the track altitude confidence field shall be improved by setting to high confidence all currently low confidence bits that are high confidence in the report. Note that this improvement rule shall not be employed if both the track and report are garbled flight level. (To do so could result in a flight level being produced very different from that at which the aircraft actually resides.)

3.4.6.6.6 4096 code update.- The following code update action shall be taken depending upon confidence bit determination:

(a) All high confidence bits (if any) of the 4096 code of the correlating report agree with the track code:

- Update track code to include the union of all high confidence bits; update code confidence word accordingly;
- Set code-in-transition confidence word to all bits low confidence;
- Set code-in-transition counter to zero;

(b) Some high confidence bits of the 4096 code of the correlating report do not agree with the track code:

(1) All high confidence bits of the 4096 code of the correlating report agree with high confidence bits (if any) of the track code-in-transition code:

- Update transition code to include the union of all high confidence bits; determine corresponding code-in-transition confidence word;
- Increment code-in-transition counter by one; when counter reaches a value of 3(1-5,1), replace track code and code confidence by the transition code and transition code confidence words and set code-in-transition counter to zero.

(2) Some high confidence bits of 4096 code of the correlating report do not agree with the track transition code:

- Replace old transition code and old transition code confidence words with report code and report code confidence words;
- Set code-in-transition counter to one.

3.4.6.6.7 Discrete code update.

3.4.6.6.7.1 New discrete code track.- If, as the result of the code update in 3.4.6.6.6, a track becomes a discrete code track, it shall be treated as specified under track initiation (3.4.6.5.4.4).

3.4.6.6.7.2 End of discrete code track.- If a discrete code track is dropped in 3.4.6.10.4.1 or 3.4.6.6.4.1, or if a discrete track becomes a nondiscrete track due to code update in 3.4.6.6.6, the following action shall be taken.

- (a) If the track is in the unique code file (3.4.6.4.5.1), it shall be removed.
- (b) If only one other track has the same discrete code, this track shall be entered into the unique code file and removed from the general file.
- (c) If two or more other tracks have the same discrete code, no action shall be taken with regard to their location.

3.4.6.6.8 Mature tracks.- A track shall be considered mature when the total number of reports received is greater than or equal to K in Table 3.4.6-6.

3.4.6.7 ATCRBS fruit rejection.

3.4.6.7.1 Purpose.- The purpose is to reject potential fruit target reports if they do not correlate with a radar report.

3.4.6.7.2 Inputs.- The inputs shall be non-radar reinforced ATCRBS target reports satisfying condition (a) and one of conditions (b), (c), (d), and (e):

- (a) The target did not correlate with a track,
- (b) The report was generated by ATCRBS reply processing on the basis of two replies, one of mode A and one of mode C,
- (c) The report was generated by ATCRBS reply processing on the basis of mode C only (i.e., no mode A),
- (d) The report was one of a pair of possible code swap reports as indicated by the code swap field of the ATCRBS Target Report Data Block (Fig. 3.4.5-6),
- (e) The report occurred without a monopulse azimuth estimate (i.e., $BP(k) = 1$) as indicated by the boresight field of the ATCRBS Target Report Data Block (see 3.4.5.6.7 and fig. 3.4.5-6).

3.4.6.7.3 Outputs.- Certain target reports shall be deleted as specified in 3.4.6.7.4.

3.4.6.7.4 Rules of operation.- Target reports described in 3.4.6.7.2 shall be deleted if they do not correlate with a radar report.

3.4.6.8 Mode S position measurement selection.

3.4.6.8.1 Purpose.- The purpose of this function is to select one Mode S reply per Mode S aircraft per scan to be used in the other operations of the surveillance processing.

3.4.6.8.2 Inputs.- The inputs shall be Mode S All-Call and roll-call replies provided by Mode S preprocessing (3.4.6.3.5).

The relevant items for each All-Call reply shall be:

- (a) Mode S ID.
- (b) Off-boresight azimuth.
- (c) Target azimuth.
- (d) Range estimate.
- (e) Time-of-day of All-Call reply.

Roll-call replies are made available to surveillance processing by channel management, as specified in 3.4.1.4. Specifically, as each group of targets leaves the antenna beam, channel management outputs a released target list. This list contains an entry for each target now ready for surveillance processing and data-link processing. The structure of this list is specified in 3.4.1.4.5.1. Each entry in the released target list is a target transaction

block, consisting of a header (called the target record) and a set of transaction records. The target record contains the following information relevant to surveillance processing:

- (a) The Mode S address.
- (b) A range completion indicator.
- (c) An azimuth completion indicator.
- (d) The range delay.

The range completion indicator will be set if at least one reply was accepted by the Mode S reply processor and channel management. The corresponding reply will make possible a range measurement. The azimuth indicator will be set if at least one reply contained an acceptable azimuth determination, according to criteria imposed by the Mode S reply processor and channel management. Range delay will be used by surveillance processing in the computation of target range (3.4.6.3).

The transaction block is structured to permit successive access to the transaction records from the target record. The transaction record of each transaction for which one or more replies was received will contain a reply pointer to this reply (or replies). This pointer will indicate the location of an image of the reply (or replies) in the reply storage area, as specified in 3.4.1.6.3.

The relevant information contained in each reply is:

- (a) Failure indication (F). This is a two-bit field, specified in 3.4.4.8.2 (fig. 3.4.4-12), indicating reply quality (valid reply, no reply decoded, no reply received, no monopulse estimate included).
- (b) Target range.
- (c) Off-boresight azimuth.
- (d) Target azimuth.
- (e) AI bit.
- (f) Altitude/Identity field.
- (g) Time-of-day of reply.

Items (b), (c), and (d) above, are the results of computations performed by surveillance processing, as specified in 3.4.6.3.5.

3.4.6.8.3 Outputs.— The outputs shall be a single position measurement per target, consisting of two-way range, azimuth, and altitude (if available).

3.4.6.8.4 Rules of operation.

3.4.6.8.4.1 Case one.— Case one is when one or more roll-call replies were received for a normal Mode S track and accepted as main beam replies, according to the rules specified in 3.4.6.3.5. Let the smallest value of range, contained in the accepted replies, be denoted by ρ . The set of replies with range values

not exceeding $\rho + \Delta\rho_{\max}$ shall be selected. $\Delta\rho_{\max}$ is an adaptation parameter = $2(1-16,1)R_u$. The position measurement shall be the range, azimuth and altitude of the reply with the smallest off-boresight angle, of the s t selected above. The All-Call reports for this target, if any, shall be checked. First, the range of these All-Call replies shall be compared to the range of the selected roll-call reply. Those All-Call replies with range differences $< 8(1-64,1) R_u$ shall be retained, all others shall be discarded. Of the remaining All-Call replies, the one with the shortest range shall be labelled a false target filter reply, saved for one full scan, and used in the test for shortest range All-Call reports specified in 3.4.6.8.4.2. The position report shall then be placed in the reply/report-to-track correlated file.

The AI bit of the selected roll-call reply shall be checked. If AI = 0, the non-zero altitude field of the selected reply shall be decoded and expressed in units of 100 feet. If the altitude field equals zero, this indicates an absence of mode C encoding for that target. If AI = 1, then the altitude field of the first reply of the scan shall be retrieved. This shall be decoded and stored with the selected reply.

3.4.6.8.4.2 Case two.— Case two is when All-Call reports and no roll-call replies are received and accepted as mainbeam replies (as specified in 3.4.6.3.5) with an ID corresponding to a Mode S track already in file. These reports shall be compared in range with the false target filter reply (3.4.6.8.4.1), if any. If the false target filter reply has the shortest range, the report with which it was compared shall be discarded. If the false target filter reply does not have the shortest range, or if there is no false target filter reply, then the All-Call report with the shortest range shall be used in the following tests:

- (a) The report shall be used in a reasonableness check of report-to-track position correlation. The report shall be entered into the reply-to-track correlation file if:

$$|\Delta_{\text{range}}| < RDS_1 \cdot 2^{10} (2^9 - 2^{11}, 2^9) R_u$$

$$|\rho \Delta_{\text{azimuth}}| < RDS_2 = \frac{2^{23}}{\pi} \left\{ \frac{2^{22}}{\pi} - \frac{2^{24}}{\pi}, \frac{2^{22}}{\pi} \right\} R_u * A_u$$

where Δ_{range} is the report-to-track range difference, Δ_{azimuth} is the report-to-track azimuth difference and ρ is the track range. If the above conditions are not met, the next test shall be performed.

- (b) If the reasonableness check has failed, the report shall be used to perform the zone test specified in 3.4.6.13.4. If the report lies in a false target zone, then the image test specified in 3.4.6.13.5.2 shall be performed. If this test indicates that the report and track are images, then the report shall be discarded.

- (c) If the report does not lie in a false target zone, then the zone test shall be performed on the track. If the track lies in a false target zone, then the image test specified in 3.4.6.13.5.2 shall be performed with the roles of report and track reversed. If this test indicates that the report and track are images, then the track shall be dropped and the report processed as in 3.4.6.8.4.3. Otherwise the report shall be placed in the uncorrelated All-Call report file.

3.4.6.8.4.3 Case three.- Case three is when All-Call reports have been received and accepted as correlated replies with at least one report containing ID (as specified in 3.4.6.3.5) and there is no existing track with the same ID. If one or more reports with ID and off-boresight azimuth are present, the All-Call report with the shortest range shall be selected and placed in the uncorrelated All-Call report file.

If no report contains both ID and off-boresight azimuth then the correlated set of replies shall be discarded. #

3.4.6.8.4.4 Case four.- Case four is when All-Call reports have been received and accepted as correlated replies, but none of the report contains an ID. In this case:

- (a) The All-Call report with the shortest range shall be selected from the reports that contain range and off-boresight azimuth.
- (b) If no reports contain off-boresight azimuth, then the average of the boresight azimuths shall be calculated and inserted into the report with the shortest range. This shall be the selected report.

Reports selected in (a) or (b) above shall be used to initiate an acquisition track as specified in 3.4.6.9.4.3.

3.4.5.8.4.5 Case five.- Case five is when a roll-call reply was received from an acquisition Mode S track and accepted as a main beam reply, according to the rules specified in 3.4.6.3.5. If the ID of the acquisition roll-call reply corresponds to the ID of Mode S track already in the file, the acquisition

This space intentionally unused.

3.4.6.8.4.6 Setting of all-call flag.- If any All-Call replies are present, whether or not selected for output, the All-Call flag for this target in the surveillance file shall be set to one. Otherwise, the All-Call flag shall be set to zero.

3.4.6.9.1 Purpose - The purpose is to initiate Mode S tracks using All-Call target reports that did not correlate with any existing tracks and to eliminate those tracks that originated from false target reports. Mode S tracks are also initiated from acquisition roll-call replies and track data messages.

3.4.6.9.3 Outputs.- The output shall be tracks whose fields are set as follows:

- ### 3.4.6.9.4 Rules of operation.

3.4.6.9.4.1 Assignment of track numbers (SFN's)..- Track numbers, usually referred to as surveillance file numbers (SFN's), shall be assigned initially in sequence from 1 to the largest number available. Thereafter, numbers assigned shall be those of previously dropped tracks, with the least recently used number assigned first.

3.4.6.9.4.2 Reports with Mode S ID.- Under site adaptation control it shall be possible to cause Mode S track initiation to occur based on the receipt of
(1) two matching, uncorrelated All-Call target reports (normal mode) or
(2) one uncorrelated All-Call target report (early mode).

- (a) If normal Mode S track initiation is selected, uncorrelated All-Call target reports shall be maintained for one full scan in the uncorrelated target reports file (last scan). When a new target report is received, the file shall be searched for reports that arrived during the last scan with the same Mode S ID. The range and azimuth of the new report shall be compared in a reasonableness check as follows:

$$|\rho_{\text{new}} - \rho_{\text{old}}| < \Delta\rho = 2^7 (2^6 - 2^8, 2^6) * T_{\text{scan}}, Ru$$

$$\rho_{\text{old}} * |\theta_{\text{new}} - \theta_{\text{old}}| < \Delta\theta = \frac{2^{20}}{\pi} \left\{ \frac{2^{19}}{\pi} - \frac{2^{21}}{\pi}, \frac{2^{19}}{\pi} \right\} * T_{\text{scan}}, Ru.Au.$$

The new report shall be associated with an old report for which both parts of the reasonableness check were satisfied. If the new target report fails to pass the reasonableness check with any of the old reports, it shall be maintained as an uncorrelated reply. If an old report was not associated with a new report, the old report shall be dropped from the file.

There can exist more than one pair of target reports (one pair with real reports, other pair(s) with false reports) with the same Mode S ID. This is so because reflection mechanisms can give rise to false All-Call target reports. The reasonableness check is designed to minimize the possibility that a false target report is associated with a real target report. If there are two or more pairings, the one with the shortest range shall be kept and the other ones dropped.

- (b) If early track initiation is selected, Mode S track initiation shall be performed for each uncorrelated All-Call target report.

The following steps shall be performed for target reports selected by either normal or early track initiation processing:

A check shall be made of correlated All-Call reports to determine if a track already exists with the same Mode S address. If not then a track shall be started with track firmness equal to 3 and track history firmness equal to 0. This shall be done by entering the information required in 3.4.6.9.3 above into the surveillance file.

Smoothing and prediction of ρ , $\dot{\rho}$, θ , $\dot{\theta}$ and the calculation of earliest likely range and azimuth shall be carried out routinely along with all other tracks by Mode S track update 3.4.6.10. The All-Call report basic data-link

capability field CA (see Mode S National Standard) of the second All-Call report used in initiating a new track shall be entered into the surveillance file for that track. For tracks initiated on external data the value of CA from the track data message shall be entered. In both cases, the value of extended capability ECA shall be initialized to all zeroes.

If a track of the same ID already exists, then a new entry shall be created in a separate table, called the Duplicate Address Alert Table (DAAT). This table shall contain the following fields for each entry:

Mode S ID	(24 bits)
Active Control Flag (ACF)	(1 bit)
Aircraft 1 (track)	
Range	(16 bits)
Azimuth	(14 bits)
Counter (CTR ₁)	(4 bits)
Aircraft 2 (reply)	
Range	(16 bits)
Azimuth	(14 bits)
Counter (CTR ₂)	(4 bits)

with both CTR₁ and CTR₂ initialized to zero. The track with this Mode S address shall be dropped from the surveillance file.

If the third option of early dissemination of uncorrelated beacon reports is selected (3.4.6.14.1), then the Mode S track initiation function shall suitably indicate for dissemination that the (1) second report of the association pair forming the track initiation if normal Mode S track initiation is used, or (2) that the uncorrelated All-Call report causing the track initiation if early Mode S track initiation is used.

3.4.6.9.4.3 Reports without Mode S ID. - All-Call target reports without Mode S ID selected in 3.4.6.8.4.4 shall be used to form acquisition tracks by entering the information specified in 3.4.6.9.3 in the surveillance file.

The calculation of earliest likely azimuth shall be carried out routinely along with other tracks by Mode S track update (3.4.6.10) using a duplicate copy of the All-Call report to update the initiated track.

Acquisition tracks shall be used by channel management to schedule stochastic Mode S-Only All-Calls to obtain Mode S ID in the presence of All-Call synchronous garbling. Acquisition tracks shall be dropped after one scan since continued garbling will result in the initiation of a fresh acquisition track.

3.4.6.9.4.4 Acquisition roll-call replies.- A Mode S track shall be initiated for each acquisition roll-call reply not corresponding to an existing Mode S track. Its predicted range and azimuth shall be that of the report. Other fields shall be as specified in 3.4.6.9.3.

If both All-Call reports and an acquisition roll-call reply satisfy the conditions for initiating tracks with the same Mode S address in the same scan, the track shall be initiated using the All-Call report and the acquisition reply shall be discarded.

3.4.6.9.4.5 Track data message reports.- A Mode S track shall be initiated for each track data message report not corresponding to an existing Mode S track. The predicted range, azimuth, range rate and azimuth rate shall be those of the report. Other fields shall be as specified in 3.4.6.9.3.

3.4.6.10 Mode S track update.

3.4.6.10.1 Purpose.- The purpose is to smooth and predict Mode S tracks using Mode S or radar reports.

3.4.6.10.2 Inputs.- The inputs shall be Mode S or radar target reports correlating with Mode S tracks and the Mode S track residing in the surveillance file. The relevant items in a target report shall be:

- (a) Measured range
- (b) Measured azimuth
- (c) Mode S ID of the correlating track.

3.4.6.10.3 Outputs.- The outputs shall be updated Mode S tracks.

3.4.6.10.4 Rules of operation.- The Mode S track update function shall have two points of entry. One of these entry points shall be used when the track is being updated with a Mode S target report, an external report in the zenith cone buffer (if TRR = 1), or a correlating radar target report. The other entry point shall be used when there is neither a Mode S nor a radar target report with which to update the track (that is, there is a null target report). The operations immediately following this latter entry point constitute the coasting mechanism. Whether the track is updated or coasted, the equations used to predict the track are the same.

3.4.6.10.4.1 Updating the track with a Mode S or radar target report.-Smoothed position and velocity shall be calculated using the following equations:

$$\begin{aligned} \rho &= \rho_{\text{measured}} - \rho_{\text{predicted}} && \text{(range residual)} \\ \phi &= \phi_{\text{measured}} - \phi_{\text{predicted}} && \text{(azimuth residual)} \\ \rho_{\text{smooth}} &= \rho_{\text{measured}} \end{aligned}$$

$$\begin{aligned}\dot{\rho}_{\text{smooth}} &= \dot{\rho}_{\text{predicted}} + \beta * \epsilon \rho \\ \theta_{\text{smooth}} &= \theta_{\text{measured}} \\ \dot{\theta}_{\text{smooth}} &= \dot{\theta}_{\text{predicted}} + \beta * \epsilon \theta\end{aligned}$$

The measured values shall be obtained from the target report this scan, and the predicted values shall be obtained from the track file. The latter represent predicted values for the current scan.

The values of β used above shall depend on the magnitude of a quantity termed "track firmness", f . Track firmness is numerically equal to the number of scans since the last report. Values of β are related to track firmness in Table 3.4.6-6, except that when history firmness $g = 0$ (indicating a newly initiated track), set $\beta = 1$.

TABLE 3.4.6-6. VALUES OF β VS TRACK FIRMNESS, f

<u>Track Firmness</u>	<u>β</u>
1	1
.	.
.	.
k	1/k
.	.
.	.
K	1/K
K = 5 (3-16,1)	

After the track is smoothed, a new value of track firmness shall be determined. The transition from one firmness value to another shall depend on the present value of track firmness and whether a valid target report was received or not (i.e., what entry point was used for the program). The transition rules are listed in Table 3.4.6-7. If a report was received, the value of track history firmness g (the value of f prior to the receipt of the previous report) shall be set equal to the old firmness value, prior to calculating a new value. If a report is not received the value of g shall remain unchanged.

If a track did not have a correlating beacon or radar target report, the smoothed position and velocity shall be made equal to the predicted position and velocity. If the track is already in the last allowable firmness, the track shall be dropped.

Normal tracks shall be dropped when a firmness level of K is reached where $K = 5(3-16,1)$. For a netted Mode S sensor, Mode S tracks that enter the zenith cone (identified by TRR=1 in the surveillance file record for that track, as

TABLE 3.4.6-7. TRACK FIRMNESS TRANSITION RULES.

<u>Old Value of f</u>	<u>New Value of f, if Report Received</u>	<u>New Value of f, if Report Not Received</u>
1	f = 1	f = 2
.	.	.
.	.	.
k	f = 1	f = k + 1
.	.	.
.	.	.
K = 5(3-16,1)	f = 1	drop track
K ₂ = 3(3-16,1)		

specified in 3.4.8.2.2) shall be dropped when a firmness level of K₂ is reached when K₂ = 3(3-16,1). For a non-netted sensor the track shall be dropped upon entering the zenith cone.

Whenever a track is dropped, a notification shall be sent to the message routing management function (3.4.8.12.5.3), for the purpose of generating a track drop message.

If the track is not at the last allowable firmness, the next firmness shall be found using Table 3.4.6-7.

3.4.6.10.4.2 Predicting a track. Different track prediction rules apply in each of three regions defined on the basis of aircraft range and altitude. The region in which a track lies shall be determined according to the following rules: (Since ρ is stored as two-way range in Ru, aircraft altitude must be expressed similarly in the following equations, i.e., $\hat{h} = 2 * 1.627 * h - h_s$ where h_s = height of the sensor antenna above sea level in Ru).

If the track altitude is unknown, a pseudoaltitude \hat{h} shall be used

$$\hat{h} = 91 \text{ Ru; if } \rho_{\text{meas}} \geq 182 \text{ Ru}$$

$$\hat{h} = 1/2 \rho_{\text{meas}} \text{ Ru; if } \rho_{\text{meas}} < 182 \text{ Ru}$$

(a) A track is in region 1 if:

$$\rho_{\text{meas}} > 1052 \text{ Ru; and } \hat{h} \leq \rho_{\text{meas}} * \sqrt{2/2}$$

(b) A track is in region 2 if:

$$1052 \text{ Ru} \geq \rho_{\text{meas}} \geq 384 \text{ Ru; and } \hat{h} \leq \rho_{\text{meas}} * \sqrt{2/2}$$

(c) A track is in region 3 if:

$$\rho_{\text{meas}} \leq 384 \text{ Ru; or } \hat{h} > \rho_{\text{meas}} * \sqrt{2/2}$$

3.4.6.10.4.2.1 Predicting a track in region 1. - The track position and velocity shall be predicted according to the following equations:

$$\begin{aligned}\dot{\rho}_{\text{predicted}} &= \dot{\rho}_{\text{smooth}} + \ddot{\rho}_{\text{smooth}} \\ \dot{\rho}_{\text{predicted}} &= \dot{\rho}_{\text{smooth}} \\ \dot{\theta}_{\text{predicted}} &= \dot{\theta}_{\text{smooth}} + \ddot{\theta}_{\text{smooth}} \\ \dot{\theta}_{\text{predicted}} &= \dot{\theta}_{\text{smooth}}\end{aligned}$$

3.4.6.10.4.2.2 Predicting a track in region 2. - The prediction of position and velocity shall be made according to the equations:

$$\ddot{\rho} = \ddot{\rho}_{\text{smooth}} * (\ddot{\theta}_{\text{smooth}} * \pi^{2-13})^2$$

$$\ddot{\theta} = -2 * \dot{\rho}_{\text{smooth}} * \ddot{\theta}_{\text{smooth}} / \dot{\rho}_{\text{smooth}}$$

$$k = 1$$

(Note: For back-to-back antenna, $k \neq 1$)

$$\tau = \frac{1}{1 - k * \ddot{\theta}_{\text{smooth}} * 2^{-14}}$$

$$\dot{\rho}_{\text{predicted}} = \dot{\rho}_{\text{smooth}} + \ddot{\rho}_{\text{smooth}} * \tau + \frac{\ddot{\rho}}{2} * \tau^2$$

$$\dot{\rho}_{\text{predicted}} = \dot{\rho}_{\text{smooth}} + \ddot{\rho} * \tau$$

$$\dot{\theta}_{\text{predicted}} = \dot{\theta}_{\text{smooth}} + \ddot{\theta}_{\text{smooth}} * \tau + \frac{\ddot{\theta}}{2} * \tau^2$$

$$\dot{\theta}_{\text{predicted}} = \dot{\theta}_{\text{smooth}} + \ddot{\theta} * \tau$$

3.4.6.10.4.2.3 Predicting a track in region 3. -

- (a) When a track enters Region 3 its position and velocity shall first be converted from ρ - θ to x-y coordinates as follows:

$$x = \rho_{\text{gnd}} \sin \theta$$

$$y = \rho_{\text{gnd}} \cos \theta$$

$$\dot{x} = \frac{x \dot{\rho}}{\rho_{\text{gnd}}} + y \dot{\theta} * \pi^{2-13}$$

$$\dot{y} = \frac{\dot{y} \rho \dot{\rho}}{\rho_{gnd}^2} - \dot{x} \dot{\theta} * \pi + 213$$

where $\rho_{gnd} = (\rho^2 - \hat{h}^2)^{1/2}$

Values of x , y , \dot{x} , and \dot{y} shall be kept in the surveillance file: x and y in their own fields, \dot{x} and \dot{y} in the $\dot{\rho}$ and $\dot{\theta}$ fields.

- (b) While in Region 3 track smoothing and track prediction shall occur in x-y coordinates as follows:

$$x_{smooth} = x_{meas} = \rho_{gnd} * \sin \theta_{meas}$$

$$y_{smooth} = y_{meas} = \rho_{gnd} * \cos \theta_{meas}$$

$$\dot{x}_{smooth} = \dot{x}_{pred} + \beta * \epsilon x$$

$$\dot{y}_{smooth} = \dot{y}_{pred} + \beta * \epsilon y$$

where

$$\rho_{gnd} = (\rho_{meas}^2 - \hat{h}^2)^{1/2}$$

$$\epsilon x = x_{residual} = x_{meas} - x_{pred}$$

$$\epsilon y = y_{residual} = y_{meas} - y_{pred}$$

then

$$x_{pred} = x_{smooth} + \dot{x}_{smooth} * \tau$$

$$y_{pred} = y_{smooth} + \dot{y}_{smooth} * \tau$$

$$\dot{x}_{pred} = \dot{x}_{smooth}$$

$$\dot{y}_{pred} = \dot{y}_{smooth}$$

$$\rho_{pred} = (x_{pred}^2 + y_{pred}^2 + \hat{h}^2)^{1/2}$$

$$\theta_{pred} = \frac{213}{\pi} * \tan^{-1}(x_{pred}, y_{pred})$$

where τ is calculated as in 3.4.6.10.4.2.4 and $\tan^{-1} x, y$ is defined to be the two argument arctangent whose argument is x+y and that which returns a value in the interval 0 to 2π .

- (c) When exiting Region 3, track velocity shall be converted back to ρ , θ coordinates using prediction equations as follows:

$$\dot{\rho}_{\text{pred}} = \frac{\dot{x}_{\text{pred}} * \dot{x}_{\text{pred}} + \dot{y}_{\text{pred}} * \dot{y}_{\text{pred}}}{\rho_{\text{pred}}}$$

$$\dot{\theta}_{\text{pred}} = \frac{\dot{y}_{\text{pred}} * \dot{x}_{\text{pred}} - \dot{x}_{\text{pred}} * \dot{y}_{\text{pred}}}{\rho_{\text{gndpred}}^2} * \frac{2^{13}}{\pi}$$

3.4.6.10.4.2.4 Determination of τ . - In region 3, let τ be the time from the current track position to the next time the antenna will point at the track, normalized to one scan period. Since the track may pass very close to the sensor, there are several cases.

$$\text{Let } \dot{\rho}_{\text{gnd}} = \frac{\dot{x}_{\text{smooth}} * \dot{x}_{\text{smooth}} + \dot{y}_{\text{smooth}} * \dot{y}_{\text{smooth}}}{\rho_{\text{gnd}}}$$

$$\dot{\theta}_{\text{smooth}} = \frac{\dot{y}_{\text{smooth}} * \dot{x}_{\text{smooth}} - \dot{x}_{\text{smooth}} * \dot{y}_{\text{smooth}}}{\rho_{\text{gnd}}^2} * \frac{2^{13}}{\pi}$$

$$\lambda = - \frac{\dot{\rho}_{\text{gnd}}}{\dot{\rho}_{\text{gnd}}} \text{ and, } \dot{\theta}_r = \frac{\pi}{2^{13}} * \dot{\theta}_{\text{smooth}}$$

Case 1. If $\dot{\theta}_r = 0$ and $\lambda < 1/2$ and $\dot{\rho} < 0$, then $\tau = 1/2$

Case 2. If $\dot{\theta}_r = 0$ and $1/2 < \lambda < 1$, then $\tau = 3/2$

Case 3. If $\dot{\theta}_r = 0$ and either $\lambda > 1$ or $\dot{\rho} \geq 0$, then $\tau = 1$

Case 4. If $\dot{\rho} \geq 0$ and $\dot{\theta}_r \neq 0$, set $R = 2$ and $\tau_0 = 1$ and solve equation in section 3.4.6.10.4.2.5 with $k = 1$.

Case 5. If $\dot{\theta}_r > 0$ and $\lambda \geq 5/4$, set $R = 2$ and $\tau_0 = 1 + \frac{5/16}{\lambda}$
and solve equation in 3.4.6.10.4.2.5 with $k = 1$.

- Case 6. If $\dot{\theta}_r > 0$ and $\lambda < 5/4$ and $\dot{\rho} < 0$, set $R = 3$ and $\tau_0 = 3/2 - \lambda/5$ and solve equation in section 3.4.6.10.4.2.5 with $k = 1$.
- Case 7. If $\dot{\theta}_r < 0$ and $\lambda \geq 3/4$, set $R = 2$ and $\tau_0 = 1 - \frac{3/16}{\lambda}$ and solve equation in 3.4.6.10.4.2.5 with $k = 1$.
- Case 8. If $\dot{\theta}_r < 0$ and $\lambda < 3/4$ and $\dot{\rho} < 0$, set $R = 1$ and $\tau_0 = 1/2 + \lambda/3$ and solve equation in 3.4.6.10.4.2.5 with $k = 1$.

"This space intentionally unused"

-255b-

FAA-E-2716 & AMEND.-2
SCN-2

"This page intentionally unused."

3.4.6.10.4.2.5 Equation for τ .

$$\tau = k \left[\frac{R}{2} + \frac{1}{2\pi} \arctan \frac{\dot{\theta}_r \tau}{1 - \tau/\lambda} \right]$$

The above equation shall be solved by entering the values of k , R , $\dot{\theta}_r$, λ , and $\tau = \tau_0$ on the right side to determine a value of $\tau = \tau^1$. The new value of τ to use in the equation is then:

$$\tau_i = \frac{\tau_{i-1} + \tau^1}{2}$$

This process shall be iterated three times, or until

$$|\tau^1 - \tau_{i-1}| < .05 \text{ (}.01 \text{ - } .2, .01).$$

This equation reduces to a simpler form that shall be used in place of the above iteration. Whenever

$$|\dot{\theta}_r| < 1/3 \text{ and either}$$

$$(a) \lambda \geq 3, \text{ or}$$

$$(b) \rho > 0$$

Use

$$\tau = \frac{1}{1 - k * \dot{\theta}_r / 2\pi}$$

3.4.6.10.4.3 Earliest likely range and azimuth. - Once the position of the aircraft has been predicted, range and azimuth windows about the predicted position shall be calculated. This calculation shall include effects of prediction uncertainty due to measurement noise and possible future aircraft turns:

$$\Delta r = \sigma_\rho * (1 + 2f) + .0421 * a_g * 192 * \left(\frac{T}{4}\right)^2 * (f^2 + fg)$$

$$\Delta \theta = \max \left(\sigma_\theta, \frac{\sigma_\rho}{\rho_{pred}} * \frac{2^{13}}{\pi} * (1 + 2f) \right)$$

$$+ \frac{.0421 * a_g * 192}{\rho_{pred} * (\pi/2^{13})} * \left(\frac{T}{4}\right)^2 * (f^2 + fg)$$

but not greater than N sectors (N from 3.4.6.4.6.1).

where:

a g's of turn = 1 (0.5 - 2.0, 0.1)
f firmness per 3.4.6.10.4.1
g history firmness per para. 3.4.6.10.4.1
 σ_p 3-sigma range accuracy = 8(4-16,1) Ru
 σ_θ 3-sigma angle accuracy = 8(4-16,1) Au
T antenna scan time, seconds
 θ_E = The earliest likely azimuth = [$\theta_{\text{predicted}} - k_\theta \Delta\theta$] in azimuth units
 θ_L = The latest likely azimuth = [$\theta_{\text{predicted}} + k_\theta \Delta\theta$] in azimuth units
 ρ_E = The earliest likely range = [$\rho_{\text{predicted}} - k_r \Delta r + 2124 - RS + D_4$]
in range units
Range guard = [$2 k_r \Delta r + RS$] in range units
 $k_\theta = 1(1-16,1)$, and $k_r = 1(1-16,1)$ for normal Mode S tracks
 $k_\theta = 2(1-16,1)$, and $k_r = 2(1-16,1)$ for acquisition tracks and tracks initiated by acquisition Roll-Call reports.
RS = 80 (0 - 80, 1) Ru = Reply spacing parameter.
 D_4 = System hardware delay defined in 3.4.6.3.5.

3.4.6.10.4.4 Surveillance file update.- The surveillance file shall contain the following data after the track update has been completed.

ρ predicted	x predicted	
\cdot	\cdot	
ρ predicted	x predicted	if track in Region 3
\cdot	\cdot	
θ predicted	y predicted	
\cdot	\cdot	
θ predicted	y predicted	

ρ_{measured}
 θ_{measured}
 θ_E = earliest likely azimuth (for Mode S tracks only)
 θ_L = latest likely azimuth (for Mode S tracks only)
 ρ_E = earliest likely range (for Mode S tracks only)
 Range guard
 $\Delta \rho_{\text{max}} = \Delta r \ l_r$
 $l_r = 1(1 - 4, 1/2)$
 $\Delta \theta_{\text{max}} = \Delta \theta \ l_\theta$
 $l_\theta = 1(1 - 4, 1/2)$
 Time of measurement
 New track firmness f
 History track firmness g

3.4.6.11 Mode S and ATCRBS track data message processing.

3.4.6.11.1 Purpose.- The purpose is to use track data messages from network management (3.4.8) to initiate Mode S tracks or to reinitialize existing Mode S or ATCRBS tracks that are being coasted.

3.4.6.11.2 Inputs.- The inputs are track data messages plus items from the surveillance file. The track data messages contain at least the following:

- (a) Mode S ID or ATCRBS track file number
- (b) Last measured range: ρ_{TT} in local sensor coordinates Ru.
- (c) Last measured azimuth: θ_{TT} in local sensor coordinates Au.
- (d) Predicted range rate: $\dot{\rho}_{TT}$ in local sensor coordinates Ru/scan.
- (e) Predicted azimuth rate: $\dot{\theta}_{TT}$ in local sensor coordinates Au/scan.
- (f) Altitude
- (g) Time at which the above measurements were made.

3.4.6.11.3 Rules of operation.- When processing a track data message, the first step shall be to determine whether or not a beacon report was received within the last scan period for the given target. If such a report exists, the track data message shall be ignored. Otherwise, the next step shall be to time-adjust the track data message and enter it into the track file. The time

adjustment consists of using $\dot{\rho}_{TT}$ and $\dot{\theta}_{TT}$ to convert ρ_{TT} and θ_{TT} to the values the track would have had at the last expected update time of the local sensor. A new track shall be initiated as in 3.4.6.9.4.2 if no track exists and this is a Mode S message or the existing track shall be reinitialized with new values as specified in the following paragraph.

Using the coordinate converted values of $\dot{\rho}_{TT}$, ρ_{TT} , $\dot{\theta}_{TT}$, θ_{TT} and the quantity τ , the tracks shall be predicted. The prediction equations shall be the same as those used in 3.4.6.10.4.2 for Mode S and 3.4.6.6.4 for ATCRBS except that in determining the region in which a track lies (3.4.6.10.4.2), the system parameter EXTBL shall be used in place of the range comparison value of 1052 Ru. The system parameter EXTBL shall nominally be 4096 (2048-8192, 1024) Ru.

Track firmness shall be set equal to 1, and history firmness = 3. Track status shall be set equal to S3.

Earliest likely range and azimuth shall be calculated for Mode S targets using the equations given in 3.4.6.10.4.3.

3.4.6.12 Radar/beacon correlation.

3.4.6.12.1 Purpose.- The purpose is to use non-ground radar reports to reinforce beacon reports and to identify those non-ground radar reports that shall be used in updating coasted tracks. The radar and beacon antennas will be boresight aligned to within 0.1 degree. The correction for collimation is specified in 3.4.6.3.6.

3.4.6.12.2 Inputs.- The inputs shall be:

- (a) All ATCRBS and Mode S target reports, correlated and uncorrelated: range and azimuth.
- (b) All tracks which did not correlate with beacon (ATCRBS or Mode S) this scan: predicted range, predicted azimuth.
- (c) Digitized radar target reports, supplied by radar preprocessing (3.4.6.3.6), that are not flagged as ground targets.

3.4.6.12.3 Outputs.- The outputs shall be:

- (a) Radar reports correlating with beacon uncorrelated ATCRBS tracks. These shall go to ATCRBS track update (3.4.6.6) and to surveillance data formatting and dissemination (3.4.6.14).
- (b) Radar reports correlating with beacon uncorrelated Mode S tracks. These shall go to Mode S track update (3.4.6.10) and to surveillance data formatting and dissemination (3.4.6.14).

The following outputs shall go to surveillance data formatting and dissemination (3.4.6.14):

- (c) Radar reinforced ATCRBS target reports with track number, if any.
- (d) Unreinforced ATCRBS target reports with track number, if any.
- (e) Radar reports not correlated with any target report or with any beacon uncorrelated track.
- (f) Radar reinforced Mode S reports.
- (g) Unreinforced Mode S reports.
- (h) Radar reports which do not correlate with a target report or beacon track (for ASR-9 interface only).

The following output shall be made available to the performance monitoring function:

- (1) Collimation difference table.

3.4.6.12.4 Rules of operation.

3.4.6.12.4.1 Definitions.- The following definitions apply:

$\delta\rho_{ij}$ = The magnitude of the range difference between the i th radar report and the j th beacon report.

$\delta\theta_{ij}$ = The magnitude of the azimuth difference between the i th radar report and the j th beacon report.

$\delta\rho_{\max}$ = 50 [2-100,1] Ru.

$\delta\theta_{\max}$ = 20 [5-30,1] Au.

$\Delta\rho_{ij}$ = The magnitude of the range difference between the i th radar report and the j th beacon uncorrelated track.

$\Delta\theta_{ij}$ = The magnitude of the azimuth difference between the i th radar report and the j th beacon uncorrelated track.

Under parameter switch control, either:

(a) $\Delta\rho_{\max} = \Delta\rho_{j2\max}$ for $f_r = \min\{f, 2\}$, $g_r = 1$

$\Delta\theta_{\max} = \Delta\theta_{j2\max}$ for $f_r = \min\{f, 2\}$, $g_r = 1$

f_r and g_r are "radar track firmness" and "history radar track firmness" corresponding to the beacon track firmness quantities defined in 3.4.6.10.4.1.

Note: $\Delta\rho_{j2\max}$ and $\Delta\theta_{j2\max}$ formulas from 3.4.6.4.6.1(b), using f_r and g_r instead of f and g .

Or (b) $\Delta\rho_{\max} = 0$
 $\Delta\theta_{\max} = 0$

3.4.6.12.4.2 Association to beacon.— This step shall be to identify all the radar reports that associate with each beacon report, and to identify all the beacon reports that associate with each radar report. A radar report i and a beacon report j shall be associated if:

$$\begin{aligned} \delta\rho_{ij} &\leq \delta\rho_{\max}, \text{ and} \\ \delta\theta_{ij} &\leq \delta\theta_{\max} \end{aligned}$$

3.4.6.12.4.3 Beacon report reinforcement.— Each beacon report that has one or more radar reports associating with it shall have its radar reinforced bit set. If two ATCRBS reports associate with the same radar report, and these ATCRBS reports are a pair of possible code swap reports, as indicated by their code swap fields (see Fig. 3.4.5-7), only the correlated report (or both, if both are correlated) shall be marked as radar reinforced. The radar report that is closest to each reinforced beacon report shall be dropped unless required for dissemination to the ASR-9 (3.4.6.12.4.8). All other radar reports shall be passed along as uncorrelated radar target reports.

3.4.6.12.4.4 Association to uncorrelated tracks.— This step shall be to identify all the remaining radar reports that associate with each uncorrelated track, and to identify all the uncorrelated tracks that associate with each radar report. A radar i and track j shall be associated if:

$$\Delta \rho_{ij} \leq \Delta \rho_{\max}, \text{ and } \Delta \theta_{ij} \leq \Delta \theta_{\max}$$

3.4.6.12.4.4.1 Time-out of association to uncorrelated tracks.- When a beacon track has been uncorrelated (by a beacon report) for at least S scans, where $S = K(K-10,1)$ scans (K as specified in 3.4.6.10.4.1), and a radar report has been associated with that track for one or more of those scans, as well as on the current scan, the beacon track shall be dropped. In such cases the current radar report shall be disseminated as uncorrelated.

3.4.6.12.4.5 Single-track, single-report correlation.- This step shall be to identify all cases where a track associates with one and only one radar report and that radar report associates only with the given track. The track and the radar report shall be correlated. The radar report shall be tagged with the track number and used by track (ATCRBS or Mode S) update to update the track, and it shall also be sent to surveillance data dissemination.

3.4.6.12.4.6 Uncorrelated radar output.- All radar reports not correlated with beacon reports (3.4.6.12.4.3) or tracks (3.4.6.12.4.5) shall be sent to surveillance data formatting (3.4.6.14) for dissemination as uncorrelated radar reports.

3.4.6.12.4.7 Function timing.- Radar/beacon correlation is intended to be performed after target/track correlation. However, if processing delays due to the situations described in 3.4.6.14.1.2 would delay the function beyond the limits required to meet the 3/32 of a scan overall processing rule, the function shall proceed prior to final resolution of reports and tracks in these situations. Tracks not yet resolved shall not be used in 3.4.6.12.4.4.

3.4.6.12.4.8 Radar output for ASR-9.- If the ASR-9 interface (3.5.2.4) is present, all radar reports shall be sent to surveillance data formatting (3.4.6.14) for dissemination to that interface. Each report shall be flagged as correlated (hence used for track update or reinforcement) or uncorrelated.

3.4.6.12.5 Collimation difference table.- A table referred to herein as the collimation difference table shall be formed during radar beacon correlation. The table shall provide storage for 64 entries. Each entry shall contain the signed differences in range and in azimuth between correlated beacon and radar reports,

$$(\rho_{\text{beacon report}} - \rho_{\text{radar report}}) \text{ and } (\theta_{\text{beacon report}} - \theta_{\text{radar report}}).$$

Selection of report pairs shall be subject to the following restrictions:

- (a) The beacon report correlated with only one radar report in 3.4.6.12.4.2.
- (b) The beacon range is greater than 4000 (3000 - 6000, 500)Ru.
- (c) No more than 2 entries shall be made in the table during the processing of an azimuth sector.
- (d) The collimation difference table contains fewer than 64 entries.

This table will be read and cleared periodically by the performance monitoring function (3.4.10.3.5.3).

3.4.6.13 False target zone and image tests.

3.4.6.13.1 Purpose.— The purpose is to determine if ATCRBS target reports or Mode S All-Call target reports are false due to mainbeam reflections off known reflecting surfaces.

3.4.6.13.2 Definitions.— The following definitions shall apply: (see fig. 3.4.6-4 and fig. 3.4.6-5)

ρ_i Range of the i th target report
 θ_i Azimuth of the i th target report
 $CODE_i$ ATCRBS 4096 code of the i th target report
 $CFLAG_i$ ATCRBS 4096 code confidence word of the i th target report
 ALT_i Mode C altitude of the i th target report
 $CALT_i$ Mode C altitude confidence word of the i th target report
 AZS_j Azimuth to the start of the j th known reflecting surface
 AZE_j Azimuth to the end of the j th known reflecting surface
 r_j Range to the center of the j th known reflecting surface
 ϕ_j Orientation with respect to north of the j th known reflecting surface
 ρ_{ij} Calculated range of the postulated real target which could have caused target report i through reflections off surface j
 θ_{ij} Calculated azimuth of the postulated real target which could have caused target report i through reflections off surface j
 ρ^*_k Range of the k th real track
 θ^*_k Azimuth of the k th real track
 $\Delta\rho^1_{max} = 200 (20-400, 10) Ru$
 $\Delta\rho^2_{max} = 600 (100-1000, 20) Ru$

$$\Delta\theta^1_{max} = \text{Min} \{ 135 (20-200, 5), \frac{200(20-400, 10)}{\rho_i} * \frac{\pi}{213} \} Au$$

$$\Delta\theta^2_{max} = \text{Min} \{ 400(20-600, 10), \frac{600(100-1000, 20)}{\rho_i} * \frac{\pi}{213} \} Au$$

$$\Delta r = 100 (20-400, 20) Ru.$$

3.4.6.13.3 False target reflector file.— The quantities AZS_j , AZE_j , r_j , and ϕ_j , defined in 3.4.6.13.2, will be supplied at program adaptation. They shall be stored in a file referred to herein as the false target reflector file. Provision shall be made for the storage of information on up to 50 reflectors.

3.4.6.13.4 False target zone test.— The zone test shall be the same for ATCRBS target reports and Mode S All-Call target reports. A target report shall be considered possibly false if it lies in a false target region, or if it is uncorrelated and has an elevation angle greater than a parameter (nominally 30 degrees). A target report i lies in a false target region when:

$$AZS_j \leq \theta_i \leq AZE_j \text{ for some } j.$$

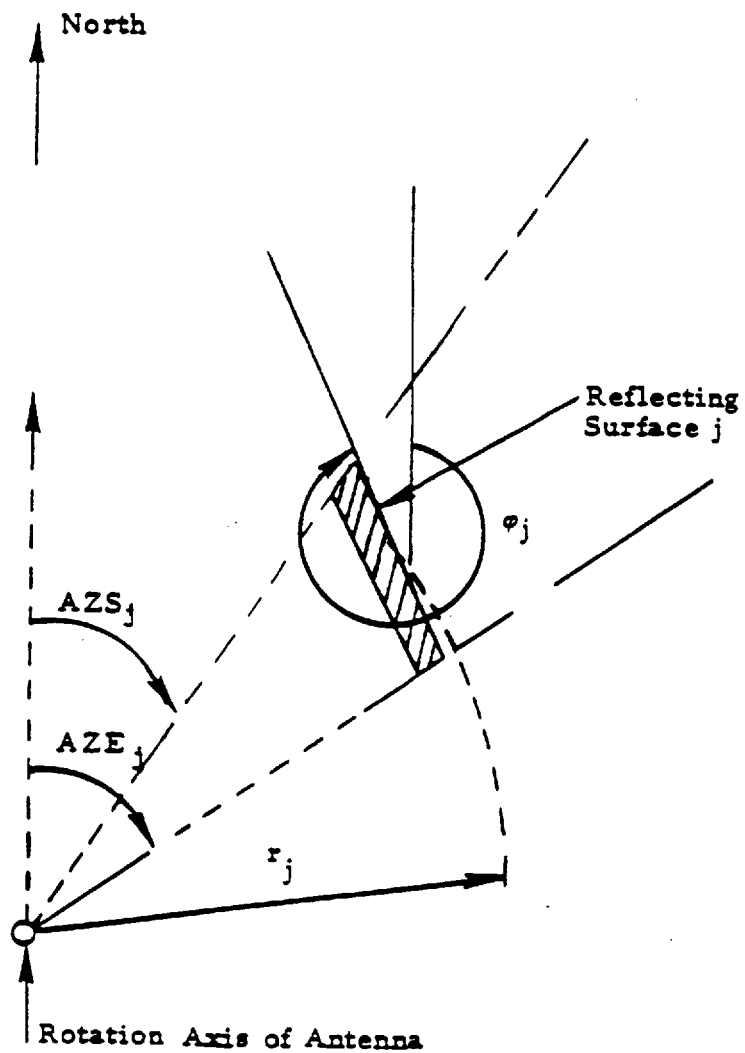


FIGURE 3.4.6-4.
POSITION AND ORIENTATION OF REFLECTING SURFACE

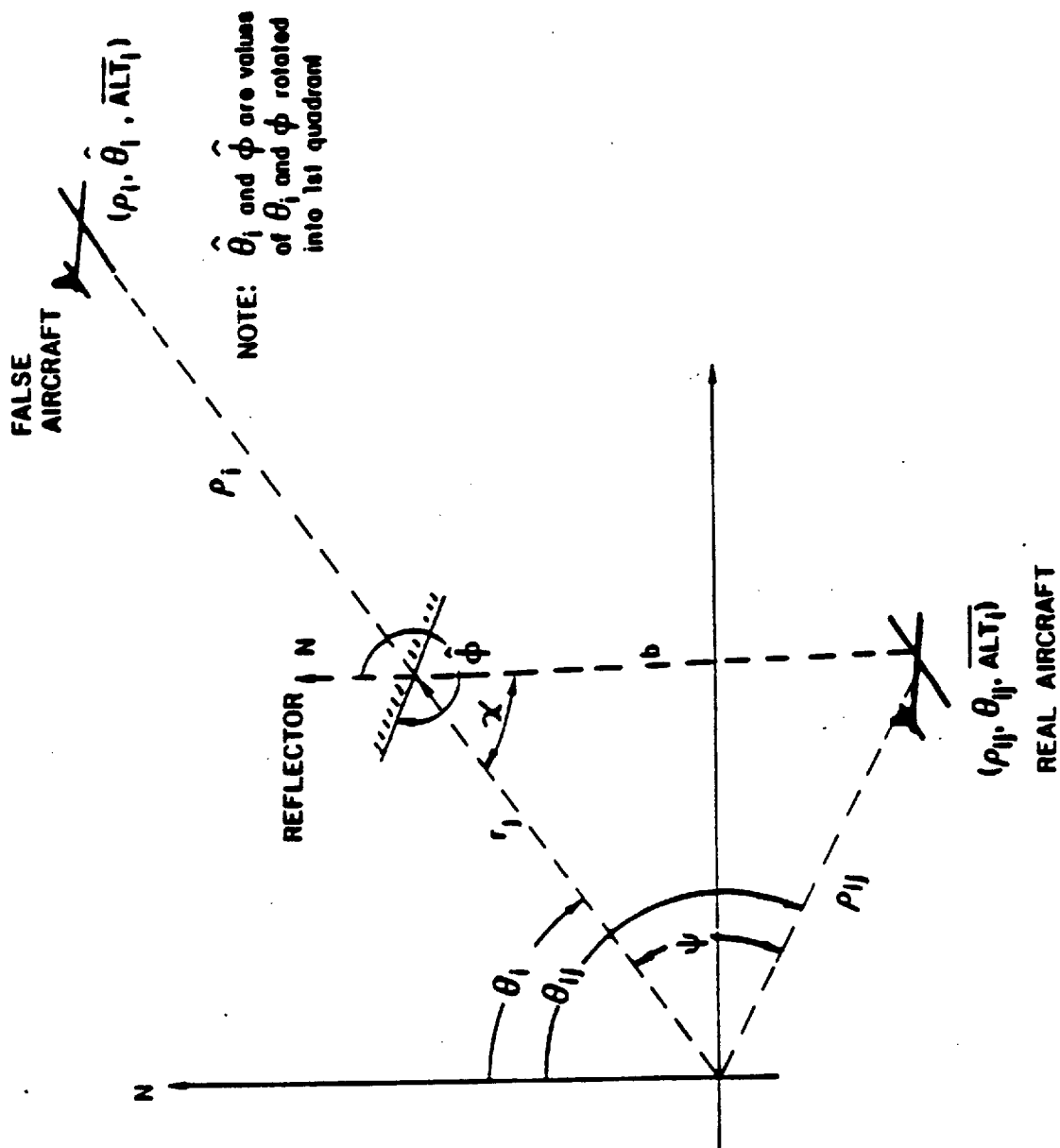


FIGURE 3.4.6-5.
COMPUTATION OF REAL AIRCRAFT POSITION.

3.4.6.13.5 False target image test.- The exact nature of this image test shall depend upon the report type.

3.4.6.13.5.1 Image test for ATCRBS.- Each postulated real-track position, (ρ_{1j}, θ_{1j}) , shall be calculated as follows:

First, in order to simplify the computation, establish an equivalent sensor-reflector-aircraft geometrical construct in the first quadrant as shown in Fig. 3.4.6-5.

Let $\hat{\theta}_1 = \theta_1$, and

$$\hat{\phi}_1 = \phi_1$$

a. If $\hat{\theta}_1 < 90^\circ$ and $\hat{\phi}_1 < 180^\circ$, $\hat{\phi}_1 = \hat{\phi}_1 + 180^\circ$.

b. If $\hat{\theta}_1 \geq 90^\circ$, then perform the following together until $\hat{\theta}_1 < 90^\circ$:

$$\hat{\theta}_1 = \hat{\theta}_1 - 90^\circ,$$

$$\hat{\phi}_1 = \hat{\phi}_1 - 90^\circ, \text{ and if } \hat{\phi}_1 < 180^\circ : \hat{\phi}_1 = \hat{\phi}_1 + 180^\circ.$$

The latter step for $\hat{\phi}_1$ guarantees that $180^\circ < \hat{\phi}_1 < 360^\circ$ as required for the following computations.

Second, calculate the range, ρ_{1j} , of the postulated real target:

$$b = ((\rho_1 - r_j)^2 - ALT_1^2)^{1/2}$$

$$\chi = 540^\circ - 2(\hat{\phi}_1 - \hat{\theta}_1)$$

$$\rho_{1j} = (b^2 + r_j^2 - 2br_j \cos \chi)^{1/2}$$

Third, Calculate the azimuth θ_{1j} , of the postulated real target:

$$\psi = \sin^{-1} \left(\frac{b \sin \chi}{\rho_{1j}} \right), \text{ then}$$

If $b^2 > (\rho_{1j}^2 + r_j^2)$, and $\psi > 0$, $\psi = (180^\circ - \psi)$, but

if $b^2 > (\rho_{1j}^2 + r_j^2)$, and $\psi < 0$, $\psi = -(180^\circ + \psi)$.

$$\theta_{1j} = \theta_1 + \psi$$

If $\theta_{1j} < 0^\circ$, $\theta_{1j} = 360^\circ + \theta_{1j}$, but

if $\theta_{1j} > 360^\circ$, $\theta_{1j} = \theta_{1j} - 360^\circ$.

Fourth, The postulated real track shall be assigned the same altitude and code as the target report.

The target report shall be declared false if the image track correlates with a real track k in the following sense:

$$|\rho_{1j} - \rho_{*k}| \leq \begin{cases} \Delta \rho_{\max}^2 & \text{if } \text{CODE}_1 = \text{CODE}_{*k}, \text{ CODE}_1 \text{ discrete} \\ \Delta \rho_{\max}^1 & \text{otherwise} \end{cases}$$

and
$$|\theta_{1j} - \theta_{*k}| \leq \begin{cases} \Delta \theta_{\max}^2 & \text{if } \text{CODE}_1 = \text{CODE}_{*k}, \text{ CODE}_1 \text{ discrete} \\ \Delta \theta_{\max}^1 & \text{otherwise} \end{cases}$$

and $\Delta h_{1k} < \Delta h_{\max}$ defined as in 3.4.6.4.4

and $\Delta C_{1k} = 0$ defined as in 3.4.6.4.4.

The target report shall be declared possibly false if it fails the above test but the image track correlates with any real track k in the following less restrictive sense:

$$\begin{aligned} |\rho_{1j} - \rho_{*k}| &\leq \Delta \rho_{\max}^2 & \text{and} & & \Delta h_{1k} &\leq \Delta h_{\max} \\ \text{and} \quad |\theta_{1j} - \theta_{*k}| &\leq \Delta \theta_{\max}^2 & \text{and} & & \Delta C_{1k} &\leq \Delta C_{\max} \end{aligned}$$

The target report shall be declared real if it fails both of these tests.

In the above equations, the superscript *, and subscript k, refer to the kth real track used in the correlation test.

3.4.6.13.5.2 Image test for Mode S.- An All-Call report shall be considered false if an established track exists with the same code and a range that is smaller than the report by at least 1r.

3.4.6.13.5.3 Image test for potential ring-around.- Targets passing the elevation angle test in 3.4.6.13.4 shall be tested for potential ring-around. The image test shall use the range of the potential ring-around target and any azimuth, for the postulated real track position. A target report meeting the elevation angle test and that passes the zone test shall be considered as false (potential ring-around) if it meets all tests specified in 3.4.6.13.5.1, excluding all tests for track azimuth, i.e., since the track may occur at any azimuth.

3.4.6.14 Surveillance data dissemination and formatting.

3.4.6.14.1 Dissemination.- Surveillance reports shall be output from the sensor to users in accordance with the following requirements.

3.4.6.14.1.1 User types.- Under parameter control each ATC user shall be designated as a non-correlating or a correlating user of the sensor surveillance data. Non-correlating users are those which rely on the report-to-track correlation processes performed on a scan-to-scan basis by the Mode S sensor surveillance processor. make use of the track numbers as assigned by the sensors, and perform no further track correlation. External users of the data link other than ATC facilities may be designated by site adaptation as non-correlating recipients of Mode S surveillance data.

Correlating users are those which perform further correlation processing upon the surveillance data provided by Mode S. Sensor assigned track numbers may assist these processes. Most en-route sites of the National Airspace System are correlating users.

3.4.6.14.1.2 Processing delays.- Surveillance reports shall be fully processed by the ATCRBS and radar/beacon correlation functions and ready for release in less than $3/32$ of a scan period, but not before $5/64$ of a scan period, after their acquisition by the sensor. (Acquisition time as tagged by "Time-of-Day of Most Recent Interrogation" per fig. 3.4.5-5). However, some reports may have to await the possible arrival of other reports before correlation can occur due to the large azimuth uncertainty box of the track. Also, correlation may be delayed when a multiple track or a multiple report correlation situation exists (3.4.6.4.8, -.9, or -.10). Whenever the correlation rules require the correlation to be delayed beyond $2/32$ of a scan, the delay beyond $2/32$ of a scan may be added to the $3/32$ -of-a-scan limit for the report involved in these correlations. All other reports shall be processed fully within the $3/32$ limit.

3.4.6.14.1.3 Dissemination rules.-

- (a) All surveillance data, both correlated and uncorrelated, shall be available for transmission to correlating users, in less than $3/32$ of a scan period, but no sooner than $5/64$ of a scan period, after their acquisition by the sensor. Reports that have not as yet been released by the ATCRBS function because of the added delay specified in 3.4.6.14.1.2 shall, under parameter control, either be disseminated when released, or be disseminated as uncorrelated reports according to the rules specified in 3.4.6.14.1.3.1. ATCRBS reports shall be disseminated in the same azimuth ordering as received from the ATCRBS reply correlation function (3.4.5.6). Radar reports shall be disseminated in the same azimuth ordering as received from the radar interface (3.5.2).
- (b) Correlated surveillance data shall be available for transmission to non-correlating users after it is released by the ATCRBS and radar/beacon correlation function provided such release time does not exceed $4/32$ of a scan period (3.3.2.6), nor does not occur prior to $5/64$ of a scan period. Any report held beyond this time because of the added delay specified in 3.4.6.14.1.2 shall be treated as uncorrelated (under (c)). Such a report, under control of a parameter switch, shall either later be disseminated as correlated (if it becomes correlated) at its release time or not disseminated.

(c) To provide for early dissemination of uncorrelated beacon reports, the data dissemination function shall process the reports that are entered into the uncorrelated beacon report files for both ATRBS and Mode S. The protocol shall be that the beacon track initiation functions will first process the reports before disseminating the data to non-correlating users according to one of the following options, selectable via site adaptation:

- (1) No dissemination of uncorrelated data.
- (2) Disseminate all uncorrelated beacon reports.
- (3) Disseminate the second report of a two scan association pair used by the track initiation functions to initialize new tracks. The dissemination function will distinguish the second report of an association pair by the value of the dissemination indicator contained in the report (3.4.6.5.4.5 and 3.4.6.9.4.2).

Reports that correlate with existing tracks shall be disseminated to both correlating and non-correlating users as correlated data only after the corresponding track has been declared mature. Maturity is defined as the occurrence of correlation for K scans, where K is a site-adaptable parameter with nominal value of 2(2-15, 1). If option (2) or option (3) above has been selected, reports that correlate prior to scan K shall be disseminated as uncorrelated data. Normal ATC dissemination rules shall apply to the dissemination of correlated beacon reports.

3.4.6.14.1.3.1 Processing delayed reports. - Reports not yet correlated at output time shall be processed as follows prior to their output as uncorrelated reports:

- (a) Any report pair satisfying the code swapping conditions of 3.4.6.4.6.3.1 shall have their codes swapped according to the rules of 3.4.6.4.6.3.1 and 3.4.6.4.6.3.2. The associations of all such reports shall be resolved according to the rules of 3.4.6.4.6.4 through 3.4.6.4.6.6. If either report, as a result of this resolution, is left with no association, it shall be rejected, and not output to the users.
- (b) Any report having a Type I permanent association, identified according to 3.4.6.4.6.2.1 I, to one and only one track, and whose Mode A code matches that of this track, in all bits (high and low confidence), shall be output with its Mode A code confidence bit set to 1.
- (c) Any report having a Type I permanent association, identified according to 3.4.6.4.6.2.1 I, to one and only one track, and whose altitude has not been decoded, shall have its altitude decoded as in 3.4.6.3.4(c) and have its Mode C indicator bit set to 1 if condition 3.4.6.4.15(c) applies relative to that track.

3.4.6.14.2 Formatting. - This function shall provide the surveillance link messages and formats, including any special timing and performance requirements, as specified in FAA-RD-80-14. FAA-RD-80-14 may have more than one surveillance link message format specified, the choice of any one surveillance link message format for the sensor shall be a site adaptable parameter.

Except as provided for in FAA-RD-80-14, when messages are created with data only from some connected primary radar (i.e. no sensor generated data in the message), these messages cannot be produced when that primary radar data is not available for the sensor.

It shall be possible to modify these report formats by suitable change in software or firmware to permit all of the following: 1) re-assignment of information to different fields within the message, 2) truncation of data values, and 3) substitution of other information items stored in the surveillance file in place of presently specified items.

Any part of this formatting function may be implemented in software in the communications subsystem.

Formats that require the conversion of two-way range in Ru to one-way range in rmi shall use a speed of light of 299.71 meters/microsecond for this conversion.

For message formats that require time in storage; the sensor shall provide the total time in storage representing the difference between the time of antenna passage of the azimuth in the message (time of measurement if measured data) and the time of the current antenna azimuth when the first bit of the message leaves the sensor's modem interface drivers. The accuracy shall be ± 0.9 lsb of the smallest lsb of the time in storage fields.

For messages created with azimuth data from the connected primary radar, the time in storage may be calculated using local sensor antenna scan rate in conjunction with the azimuth in the message and the azimuth when the first bit of the message leaves the sensor's modem interface drivers. Variations in antenna scan rate need not be considered as part of the accuracy of this time in storage.

This space intentionally unused.

3.4.6.14.2.1 Diffraction flagging. - Before dissemination, each Mode S and ATCRBS surveillance report shall be tested to determine if it falls within a diffraction zone. Sensor diffraction zones will be defined at program adaptation and will include:

θ_{start} - the start azimuth of a diffraction zone.

θ_{end} - the end azimuth of a diffraction zone.

ϕ_{\max} - the maximum elevation angle subtended by the diffractor above a horizontal plane through the antenna.

Provision shall be made for storing information on up to 50 diffraction zones. The diffraction flag shall be set to one in a Mode S or ATCRBS surveillance report of:

$\theta_{\text{start}} \leq \text{report azimuth} \leq \theta_{\text{end}}$; and,
report elevation $\leq \phi_{\max}$

Report elevation is defined as the elevation angle above a horizontal plane through the antenna. It shall be calculated from report range and altitude, with correction made for curvature of the earth. Beacon reports without reported altitude shall be flagged as being in a diffraction zone if they satisfy the azimuth test.

The diffraction flag value shall be stored in the surveillance file and shall be available to users performing netted surveillance.

3.4.6.14.3 Dissemination. - If the coverage area of the Mode S sensor overlaps with the control area of more than one ATC facility, and all ATC facilities are operating normally, the destination of reports to these facilities shall be determined based on a dissemination lookup table. The lookup table shall consist of 32 rows (one row or entry for every $11\text{-}1/4^\circ$ azimuth-sector). The number of columns in the table shall correspond to the number of ATC facilities the Mode S sensor interfaces with.

For each row and column a single dissemination rule shall be expressed. Two options for this rule shall be "Do not disseminate" and "Always disseminate." All other options shall be expressed by a range and an altitude condition, both of which must be satisfied in interpreting the rule. Each condition shall be of the form:

- (a) Disseminate reports with range (altitude) less than maximum value given here, or
- (b) Disseminate reports with range (altitude) greater than the minimum value given here.

The dissemination lookup table shall be bypassed only when a connected ATC facility has failed, provided that the bypass has been allowed via a site-adaptable parameter. In this event all reports shall be disseminated to all (remaining) ATC facilities. Determination of an ATC facility failure shall be signaled by a flag set for this purpose by the message routing function (3.4.8.12.5.3).

The radar reports normally disseminated to ATC shall only be those for which no corresponding beacon report was found and that were within the area defined by the ATCRBS/radar range mask (see 3.4.8.3.6).

Surveillance reports for external users shall be placed in the appropriate output buffer of the ATC interface.

3.4.7 Data link processing.

3.4.7.1 Introduction.- This section describes the management of data-link messages and associated files. The messages are mainly those uplink and downlink messages defined in the Mode S National Standard as Comm-A, Comm-B, uplink ELM, and downlink ELM. Linked Comm-A messages, as designated by the message originator, are included. The uplink messages may originate with several different users of the data link, including both ATC facilities and other facilities referred to as "non-ATC" users. They are read by the input message processor (3.4.7.2) from a common buffer, the input message queue, having been placed there by the message routing function (3.4.8.12). After processing by the input message processor, they are available to the channel management function (3.4.1) in the form of an active message list (3.4.7.2.4). Downlink data are read with the aid of the released target list (3.4.1.4.5.1) by the output message processor (3.4.7.3). They are processed to produce appropriately addressed messages in the output buffer (3.4.7.3.3).

3.4.7.2 Input message processor.

3.4.7.2.1 Purpose.- The purpose of the input message processor is to process messages in the order received from external users via the communications interfaces (3.5.3) and the message routing function (3.4.8.12) or from internal users, and to set up a priority-ordered active message list. The external priority is received from the users as specified in FAA-RD-80-14.

3.4.7.2.2 Inputs.- The primary inputs shall be messages from ground users of the data link. (Air-to-ground inputs are considered in 3.4.7.3) They shall be read from the input message queue in the order in which they are written there by the message routing function, as specified in 3.4.8.12. Input messages present in the queue shall be those messages which have already passed an acceptance test. That is, input messages are rejected or delayed unless the Mode S target addressed is listed in the surveillance file in a suitable track state, as specified in 3.4.8.12. Certain input messages (ELM uplinks) will also have been rejected if the sensor is not designated "primary" for the Mode S target addressed or if the target lacks ELM capability. For each accepted message, the storage location in the surveillance file for the target addressed shall have been appended by message routing.

3.4.7.2.2.1 Input message types.- There shall be five types of input message in the queue, as defined in FAA-RD-80-14. The types and the data fields contained in each shall be as follows:

- | | |
|---------------------|---|
| (a) Tactical uplink | <ul style="list-style-type: none"> - Type code Sender ID Mode S ID Message number (MSG No.) Time to expiration (EXP) |
|---------------------|---|

- Priority (P)
- Packet Type (PT)
- Segment count (SC)
- Message data (Sequence of MA fields)
- (b) ELM uplink
 - Type code
 - Sender ID
 - Mode S ID
 - Message number (MSG No.)
 - Time to expiration (EXP)
 - Priority (P)
 - Length
 - ELM Text (sequence of MC's)
- (c) Request for downlink data
 - Type code
 - Sender ID
 - Mode S ID
 - Message number (MSG No.)
 - Time to expiration (EXP)
 - Priority (P)
 - Comm-B definition (BDS, comprised of BDS1 and BDS2)
- (d) ATCRBS ID request
 - Type code
 - Sender ID
 - Mode S ID
 - Message number (MSG No.)
- (e) Message cancellation request
 - Type code
 - Sender ID
 - Mode S ID
 - Message number (MSG No.)
 - Referenced message number (REF. MSG No.)
 - Referenced type code

3.4.7.2.2.2 Data fields.- Except for sender ID, the definition and coding for each data field listed shall be as specified in FAA-RD-80-14.

3.4.7.2.2.3 Sender ID.- Sender ID is not supplied by the sender, but shall be affixed to each incoming message by the appropriate interface equipment, as specified in 3.5 for inputs from other Mode S sensors and for inputs from ATC and non-ATC facilities.

3.4.7.2.2.4 Other inputs.- Before a target enters the antenna beam, the channel management function must process data on it in the surveillance file and associated files as specified in 3.4.1. While this process is taking place, it is necessary briefly to inhibit other processing functions from writing into these files. To accomplish this task, the transaction preparation function of channel management shall set a target closure flag (3.4.1.3.3) in the surveillance file when a given target becomes unavailable. The surveillance file provides the only other inputs needed by the input message processor.

3.4.7.2.3 Outputs.- For tactical uplink messages, ELM uplink messages, and requests for downlink data, the output resulting from each input message shall consist of one or more new entries in the active message list together with updating of the header of that list (more than one entry shall result in the case of a linked tactical or linked ELM uplink message). For a message cancellation request, the output shall consist of the appropriate deletions from the active message list. For an ATCRBS ID request, the output shall consist of the setting of a one-bit flag, denoted AI, in the surveillance file and of header data in the active message list.

3.4.7.2.4 Active message list.- The active message list shall support the functions and contain the elements specified herein. It may have the following or any functionally equivalent structure. For a given Mode S target, a pointer in the surveillance file (3.4.6.2) shall give the address in storage which contains the header or control block of the active message list for that target. If a target has no data-link activity pending, however, the active message list for that target shall not exist, and the pointer shall so indicate. The control block shall contain control data as needed to support the input message processing, output message processing, and transaction preparation functions. Such control data shall include, but not be limited to, location indicators to any or all of three sublists which comprise the remainder of the active message list. The sublists are as follows:

- (a) Comm-A sublist, containing all relevant data on all pending tactical uplink messages (3.4.7.2.5.2). Each entry defines a single Comm-A transmission.
- (b) Comm-B sublist, containing all relevant data on all pending requests for downlink data (3.4.7.2.5.3) as well as on pilot-initiated tactical downlink messages (3.4.7.3.4.5, (b)). Each entry defines a single Comm-B transmission.
- (c) ELM sublist, containing all relevant data on all pending ELM uplink messages (3.4.7.2.5.4) as well as on pilot-initiated ELM downlink messages (3.4.7.3.4.2). Each entry defines either an uplink ELM (two or more Comm-C interrogations with a single Comm-D reply), or a complete downlink message (a single Comm-C interrogation with one or more Comm-D replies). An uplink entry may correspond to a complete unlinked message or to one component of a linked message.

The entries in each sublist will be priority-ordered, with the highest priority message first. Within a single priority class, entries will be in the order received; that is, the order in which they are read from the input message queue. The maximum number of such priority classes is determined by the length of the priority (P) field, which may differ according to message type. In no case will the P field be longer than four bits.

3.4.7.2.4.1 Control block.- The control block of the active message list shall contain location indicators for each of the three sublists, which may include pointers and length parameters or functionally equivalent information. The absence of a particular sublist shall be indicated by null values. In addition, the control block shall contain the following data fields:

- (a) Comm-B state (3 bits). This variable defines the state of pilot-initiated activity on the downlink Comm-B channel. There are six state values: "Inactive", "B pending, normal", "B pending, multi-site", "B busy", "Clear B pending, normal", and "Clear B pending, multi-site".

These values are identical with those defined in 3.4.1.3.4.2 for target records. Common code assignments shall be used.

- (b) Comm-C state (3 bits). This variable defines the state of uplink ELM activity. There are five state values, defined and coded as in 3.4.1.3.4.2: "Inactive", "C pending, normal", "C pending, multisite", "Clear C pending, normal", and "Clear C pending, multisite".
- (c) Comm-D state (3 bits). This variable defines the state of downlink ELM activity. There are five state values, defined and coded as in 3.4.1.3.4.2: "Inactive", "D pending, normal", "D pending, multisite", "Clear D pending, normal", and "Clear D pending, multisite".
- (d) Sender ID for AI request (5 bits). This field contains the ID code of any user of the system who has requested receipt of ATCRBS identity code for the Mode S aircraft.

Coding for the control block shall be such that, if no data-link activity is pending, the control block shall be entirely deleted without loss of information.

3.4.7.2.4.2 Contents of Comm-A sublist.- Each entry of a Comm-A sub-list shall contain the following data fields:

- (a) Sender ID
- (b) Message number (MSG No.)
- (c) Time to expiration (EXP)

- (d) Priority (P)
- (e) Packet Type (PT)
- (f) Segment count (SC)
- (g) Not used
- (h) Message data (MA)
- (i) Tactical message subfield (TMS)
- (j) Completion indicator
- (k) Entry indicator

Except for the last three items, the items of this list shall correspond to data fields of a tactical uplink message in the input message queue, as specified in 3.4.7.2.2.1. Other fields included there (type code and Mode S ID) are implicit in the structure of the active message list and shall not be present. For a linked Comm-A message, designated by a segment count SC greater than zero, the message data shall consist of a single MA field. The particular segment shall be identified by data within the tactical message subfield TMS, a 4-bit field whose setting is defined in 3.4.7.2.5.2. Completion indicator is a 1-bit tag which shall be initially set to zero. Entry indicator shall provide a means for uniquely locating a particular entry in the sublist, either explicitly by means of a serially-assigned binary integer, or in some functionally equivalent manner. The entry indicator field length shall be sufficient to provide for the maximum number of messages which might be active for any single target (at least 10).

3.4.7.2.4.3 Contents of Comm-B sublist. - Each entry of a Comm-B sublist shall contain the following data fields:

- (a) Sender ID
- (b) Message number (MSG No.)
- (c) Time to expiration (EXP)
- (d) Priority (P)
- (e) Comm-B definition (BDS)
- (f) Message data (MB)
- (g) Completion indicator
- (h) Entry indicator

Except for the last three, the items of this list shall correspond to data fields of a request for downlink data in the input message queue, as specified in 3.4.7.2.2.1. Completion indicator and entry indicator shall be as defined for the Comm-A sublist in 3.4.7.2.4.2. Message data is initially not set, and it may be replaced with a pointer to a location where MB is stored.

3.4.7.2.4.4 Contents of ELM sublist. - There shall be two kinds of entries in the ELM sublist. These types are defined and their contents listed in the following two subparagraphs.

3.4.7.2.4.4.1 Uplink ELM. - One or more uplink ELM entries shall result from input message processing of a new ELM input message, as specified in 3.4.7.2.2.1. Each such entry shall contain the following data fields:

- (a) Sender ID
- (b) Message number (MSG No.)
- (c) Time to expiration
- (d) Priority (P)
- (e) Length
- (f) Entry indicator
- (g) Reply type code (RC)*
- (h) Segment number (NC)*
- (i) ELM text (MC)*
- (j) Completion indicator*

* Repeated for each segment

Items (a) through (d) of this list refer to the entire message and shall occur once in each entry. Their values correspond to data fields of an ELM uplink message in the input message queue, as specified in 3.4.7.2.2.1. Item (e), the length (the number of segments in the entry), is a binary integer with a maximum value of 15, set in each entry as specified in 3.4.7.2.5.4. RC, NC, and MC shall be coded as specified for a Comm-C uplink transmission in the Mode S National Standard. Completion indicator and entry indicator shall be coded as specified for the Comm-A sublist in 3.4.7.2.4.2.

When a message is comprised of more than one entry, suitable indication shall also be made to indicate which entries form a linked set belonging to the same message.

3.4.7.2.4.4.2 Downlink ELM.- A downlink ELM entry shall not be affected by operation of the input message processor. It shall result from operation of the output message processor, as specified in 3.4.7.3.4.2. Not more than one such entry may be present in a sublist, and it shall contain the following data fields:

- (a) Sender ID
- (b) Message No.
- (c) Time to expiration - 63 (no expiration, see 3.4.7.3.4.5)
- (d) Length
- (e) Remaining length
- (f) Entry indicator
- (g) Reply type code (RC)
- (h) Segment number (NC)
- (i) MC field (not repeated)
- (j) Completion indicator
- (k) Downlink ELM text (MD, repeated for each segment)

3.4.7.2.4.5 Order of sublist entries.- Within each sublist, entries shall occur in the order in which the inputs are read from the input message queues except that:

- (a) For each sublist, all entries having a given priority shall be grouped together and shall precede all entries having numerically lower priority values;

- (b) For the ELM sublist, any ELM uplink entries shall be ordered as in (a) above, and shall precede any downlink ELM entry.

However, in each sublist, if either a linked message (except linked Comm-B) or an uplink ELM is present which was partially completed during a previous scan, all entries compromising that message shall remain at the beginning of the sublist.

3.4.7.2.4.6 Message data.- The preceding specifications of active message list contents have included message text data (MA with associated TMS field and MC fields). In order to minimize redundant storage and transfer of these long fields it may be preferable to include them by reference. That is, the data fields may be replaced by pointers to their storage locations.

3.4.7.2.5 Rules of operation.- The entire operation of input message processing shall be based on reading out messages from the input message queue. Each message readout shall generate a self-contained procedure, defined by the type code of the message.

3.4.7.2.5.1 "Closed target" testing.- Input message processing shall be performed only on targets which are not designated "closed." For all input messages, the operation shall begin with a reading of the target closure flag to see if the Mode S target addressed in the input message is available. This flag may have been set by channel management, as specified in 3.4.1.3.3. If that target is closed, the message shall be left in the queue for processing at a later time, and the operation shall proceed with the next message, if any. If the target in question is not closed, processing of the message shall continue.

3.4.7.2.5.2 Tactical uplink message processing.- If the type code of the message being processed indicates that it is a tactical uplink message, the operation shall consist of creating new entries in the Comm-A sublist of the active message list, as specified in 3.4.7.2.4.2. The number of such entries is determined by the segment count (SC) of the message. If there is more than one segment, the message comprises a set of "linked Comm-A's", and an entry shall be created for each segment, with the entries in the same order as the segments. To insert the new entries, the surveillance file shall first be read for a pointer to the header of the existing active message list for that target, if any. If an active message list does not exist, a new one shall be created and the appropriate pointer to it shall be set. The header data of the active message list shall next be read to see if a Comm-A sublist already exists. If not, a new one shall be created and the appropriate header data set. Each new entry shall be inserted after any entries already present having the same value or a numerically higher value of priority (P), and before any entries already present having a numerically lower value. If a partially completed linked message is already present, the ordering rule in 3.4.7.2.4.5 shall override.

In each entry, a value of the tactical message subfield TMS shall be assigned. The high-order bit shall be set equal to the value of packet type PT, and the remaining three low-order bits shall be set as follows:

- (a) If the entry contains an unlinked Comm-A (SC=0), the low-order bits of TMS shall be set to 000.
- (b) If the entry contains the first segment of a linked Comm-A (SC greater than 0), the low-order bits of TMS shall be set to 001.
- (c) If the entry contains the second segment of a linked Comm-A having more than two segments (SC greater than 1), the low-order bits of TMS shall be set equal to 010.
- (d) If the entry contains the third segment of a linked Comm-A having four segments (SC=3), the low-order bits of TMS shall be set equal to 011.
- (e) If the entry contains the final segment of any linked Comm-A (SC greater than 0), the low-order bits of TMS shall be set equal to 100.

In the entry, the 3-bit message field EXP shall be recoded into a 6-bit binary integer, as follows:

<u>Message EXP</u>	<u>Entry EXP</u> <u>(decimal value of scan count)</u>
000 (default)	8 (2-16,1)
001	1
010	2
011	4
100	8
101	16
110	32
111	63

The value 63 shall be interpreted as "no expiration", rather than as a scan count. As an alternative to no expiration, an expiration of 255 scans decremented normally, may be implemented as "no expiration."

3.4.7.2.5.3 Downlink request processing.- If the type code of the message being processed indicates that it is a request for downlink data, the operation shall consist of creating a new entry in the Comm-B sublist of the active message list, as specified in 3.4.7.2.4.3. Insertion of the new entry shall follow procedures similar to those in 3.4.7.2.5.2.

3.4.7.2.5.4 ELM uplink message processing.- If the type code of the message being processed indicates that it is an ELM uplink, the operation shall consist of creating one or more new entries in the ELM sublist, as specified in 3.4.7.2.4.4. The number of entries created shall be at least one and not greater than four, depending on the parameter "ELM length" of the message. (ELM length expresses the total number of segments in the message, which may be any value between two and 64, inclusive.) Each non-final entry shall consist of 16 segments, the final entry shall consist of 16 or fewer segments. The segments and the entries shall be ordered the same as the segments in the message. If only one segment remains in the message for the final entry, an additional segment shall be created for that entry, with an MC field consisting of all zeros. Insertion of the new entry shall follow procedures similar to those specified in 3.4.7.2.5.2, to achieve the order specified in 3.4.7.2.4.5.

Whenever an ELM uplink message is processed, the new ELM target flag in the surveillance file shall be tested. If this flag is set to 1, it shall be reset to 0 and the value of the Comm-C state shall be changed to "clear C pending, normal", regardless of the value of the unconnected sensor flag USF (3.4.8.2.5). If the flag is not set and the Comm-C state is "inactive", it shall be changed to "C pending, normal" if USF=0 and to "C pending, multisite", if USF=1.

3.4.7.2.5.5 Message cancellation request.- If the type code of the message being processed indicates that it is a message cancellation request, the operation shall consist of deletion of the referenced message from the active message list. A search shall be made using the referenced type code to determine which of two possible sublists shall be searched for a match on sender ID and on referenced message number. (Message numbers are not unique for all messages for a given target but will be unique for those messages associated with a particular sender.) If no match is found, the operation shall end. If a match is found, all entries corresponding to the referenced message shall be deleted. If the message being cancelled is an ELM uplink, some segments of which have been delivered (as shown by completion indicators), the Comm-C state shall be set to the value "clear C pending, normal" or "clear C pending, multisite" as in 3.4.7.3.4.5, item (c). If the deletion empties a sublist, data in the header shall be appropriately updated.

3.4.7.2.5.6 ATCRBS ID request.- If the type code of the message being processed indicates that it is an ATCRBS ID request, no entries shall be made in any sublist of the active message list. Instead, the AI flag in the surveillance file shall be set to "1". Also, the sender ID of the request shall be entered in the control block of the active message list. If the AI flag is already set to "1", the sender ID field shall be set to all zeroes, but suitable indication shall be made that an external ID request is pending. If another ATCRBS ID request is processed during the same scan, the sender ID field shall remain all zeroes.

3.4.7.3 Output message processor.

3.4.7.3.1 Purposes. - The purposes of the output message processor are:

- (a) To process message data from downlink replies, as read from the target records, producing as outputs messages to the data link users, and
- (b) On a once-per-scan-per-target basis, to update the active message list, using downlink data, and to report to the senders on the delivery of their uplink messages.

3.4.7.3.2 Inputs. - The principal inputs are the target roll-call replies, as read with the aid of the released target list and its associated transaction records, written by the channel management function as specified in 3.4.1.4.5.1. The presence of a target in the released target list indicates that the target is no longer active and its files are fully available. That is, the target has effectively passed out of the antenna beam, or all pending link transactions involving the target have been completed, whichever occurs first.

3.4.7.3.2.1 Downlink replies. - There are several types of Mode S roll-call replies. They are defined, together with all of their data fields, in the Mode S National Standard. For each type of Mode S reply, the following data fields shall comprise the useful input to the output message processor:

- (a) Surveillance Reply - Mode S address
(DF = 4 or 5)
 - DR (containing downlink ELM request with segment count)
 - FS (containing pilot alert signal)
 - ATCRBS ID (if present, as indicated by format code DF = 5)
 - UM (containing multisite data)
- (b) Comm-B Reply - Mode S address
(DF = 20 or 21)
 - DR
 - FS
 - ATCRBS ID (if present, as indicated by DF = 21)
 - UM
 - MB (message data)
- (c) Comm-D Reply - Mode S address
(DF = 24)
 - KE (Comm-D format control)
 - ND (Segment number)
 - MD (message data)

3.4.7.3.2.2 Released target list.- As specified in 3.4.1.4.5.1, the released target list shall contain a complete record of channel management activity for a given target. The target record (header) shall indicate whether any replies were received (range completion indicator), and the state of Comm-B, Comm-C, and Comm-D channels. For each transaction, a transaction record shall include entry indicators referencing the appropriate active message list entries and reply location indicators for the associated replies. Transaction type codes in each transaction record shall identify the entry indicators as referencing Comm-A, Comm-B or ELM sublist entries. For ELM entries, the type codes shall further identify the transaction entry as uplink ELM, or downlink ELM. For multi-segment uplink ELM's there is a further tag on the reply location indicator which shall identify the last reply received. The transaction record also contains the utility message request flag UMF.

3.4.7.3.2.3 Other inputs.- Additionally, the output message processor shall make use of data stored in the active message list.

3.4.7.3.3 Outputs.- The principal outputs are messages to data-link users. Such messages shall be formatted by the output message processor and placed in the appropriate buffer for further processing by the message routing function (3.4.8.12.6) and delivery to the appropriate output interface.

3.4.7.3.3.1 Output message types.- There are seven types of output messages. They are defined, together with their data fields, in FAA-RD-80-14. The types and their contents are (messages (a), (f), and (g) are forms of tactical downlinks):

- | | |
|------------------------------------|---|
| (a) Pilot downlink | -- Type code
User ID
Mode S address
Segment count (SC)
Message data (Sequence of MB fields) |
| (b) ELM downlink | - Type code
User ID
Mode S address
Segment count (LENGTH)
ELM text (from all MD fields) |
| (c) ATCRBS ID notice | - Type code
User ID
Mode S address
ATCRBS ID |
| (d) Uplink message delivery notice | - Type code
User ID
Mode S address
Referenced message number
Delivered/Expired indicator (DI) |

- (e) Data link capability
 - Type code
 - User ID
 - Mode S address
 - Capability data
 - (including subfields CA and ECA).
- (f) Broadcast downlink
 - Type code
 - User ID
 - Mode S address
 - Message data (MB field)
- (g) Ground-initiated downlink
 - Type code
 - User ID
 - Mode S address
 - BDS1, BDS2
 - Message data (MB field)

3.4.7.3.3.2 Data fields.- Except for user ID, the definitions and coding for each data field listed shall be as specified in FAA-RD-80-14.

3.4.7.3.3.3 User ID.- For each output message which refers to some input message, the value of the user ID code shall be identical with that of the sender ID of the input message. These cases include a tactical downlink (when it is in response to a request for downlink data), and ATRBS ID notice (when in response to an ATRBS ID request), and an uplink message delivery notice. All other output messages have no corresponding sender IDs, and their user ID codes are all zeroes. The all-zero code value shall indicate that the message shall be sent to all appropriate users, as determined by the message routing function (3.4.8.12.6).

3.4.7.3.3.4 Other outputs.- In addition to output messages, there are numerous outputs taking the form of internal file updates, particularly of the active message list. These include:

- (a) Active message list
 - Setting of completion indicators
 - Updating of time to expiration
 - Updating of state variables in the control block
 - Deletion of entries
 - Insertion of new entries
- (b) Surveillance file
 - Setting of control flags (AI, capability request CAP)
 - Resetting of target closure flag

3.4.7.3.4 Rules of operation.- The output message processor shall begin by picking up a newly released target from the released target list. The information on such a target in the list shall consist of a target record and a set of transaction records (3.4.7.3.2.2). Operations shall be triggered by specific data fields within a target record, as follows:

- (a) Mode S address - The target closure flag in the surveillance file entry belonging to this target shall be reset, to indicate its availability.
- (b) Range completion indicator - If this indicator shows that no replies were received, then the processor shall omit all reply-based functions and shall proceed directly to active message list updating tasks

(3.4.7.3.4.5). If one or more replies have been received, processing shall continue in sequence.

- (c) Comm-B state, Comm-C state, and Comm-D state - These control fields shall be copied from the target record (3.4.7.3.2.2) to the control block in the active message list (3.4.7.2.4.1). If there is pilot-initiated Comm-B activity, further response is required, as specified in 3.4.7.3.4.5, item (b). If the Comm-B state is "B-busy" further response is required, as specified in 3.4.7.3.4.3.

The processor shall next proceed with reply-based processing, using each transaction record in sequence as an input, together with the replies referenced in each transaction record. The handling of replies is specified for each reply data field of interest (rather than by reply type) in the following four sub-sections (3.4.7.3.4.1 through 3.4.7.3.4.4).

3.4.7.3.4.1 ATCRBS ID code data and alert. - Every standard reply (surveillance and Comm-B) shall be read for the presence of an alert (expressed by either of the values 010, 011 or 100 in the FS field, bits 6-8) and the presence of an ATCRBS ID code (expressed by either of the values 00101 or 10101 in the DF field, bits 1-5). If present, the ATCRBS ID code value is contained in the field ID, bits 20-32, encoded as specified in the Mode S National Standard. For clarity in defining the actions to be taken in the remainder of this paragraph, the presence of a pilot alert in a reply is expressed as "A is set" and the presence of an ATCRBS ID code as "AI=1". There are four cases:

- (a) If A is set in any one or more replies but AI has the value "0" in all replies, the response shall be to set the AI flag in the surveillance file to "1" and to set the sender ID field in the active message list control block to "all zeroes."
- (b) If A is set in any one or more replies and AI has the value "1" in any one or more replies, the response shall first be to reset the AI flag in the surveillance file to "0" and to retrieve the sender ID field in the active message list control block and the ATCRBS ID code value stored in the surveillance file. If the sender ID field is not all zeroes, or if an external ATCRBS ID request is otherwise indicated, further response shall be to generate an ATCRBS ID notice in the appropriate message output buffers. If the sender ID field is all zeros and no external request is indicated, the ATCRBS ID code value in the last received reply containing such code shall be compared with the code value retrieved from the surveillance file. If the two values are the same, no further action shall be taken. If the values are different, an ATCRBS ID notice shall be generated in the appropriate message buffers. For both cases in which an ATCRBS ID notice is sent, the final actions shall be to store the ID code value used in the notice in the surveillance file and to reset the sender ID

field to all zeroes. The ATCRBS ID notice is specified in FAA-RD-80-14 and shall contain its distinctive message type code, the Mode S address, the last received ATCRBS ID code value, and the user ID code (all zeroes).

- (c) If A is not set in any reply but AI has the value "1" in any one or more replies, the response shall be to reset the AI flag in the surveillance file to "0", generate an ATCRBS ID notice as before (but with the user ID field set equal to the contents of the sender ID field in the active message list control block), and then to reset the sender ID field to "all zeroes." The ATCRBS ID code value used in the notice shall also be stored in the surveillance file.
- (d) If A is not set and AI has the value "0" in all replies, no response shall occur.

3.4.7.3.4.2 Downlink ELM request. - An air-initiated request to send a downlink ELM message is contained in the 5-bit data field DR, present in bits 9-13 of every surveillance and Comm-B reply. Such a request is present if the decimal value of DR is between 16 and 31, inclusive. In other words, a D request is present if the high-order bit 9 = "1"; for convenience this bit shall be referred to as the D-bit. If the D-bit=1, the DR field represents a request to send a message consisting of N Comm-D segments, where N is the value of DR minus 15. (N can take on values between 1 and 16, inclusive).

If the value of D is zero in all replies, no action shall be taken. If D equals one in any one or more replies, the following procedure shall be executed, once only. First, a check is made in the target record to see if the sensor is primary or secondary for this target. If secondary or if the "no communications" flag is set (3.4.10.3.5.8), no further actions shall be taken. Next a check shall be made to see whether the D request is old or new, using the Comm-D state variable in the control block. If this state value is not "inactive" the D request is old and no further action shall be taken. If the state value is "inactive" but a downlink ELM entry is present in the ELM sublist, then the D request is old and the only action shall be to delete the entry, including any segments which have been received, from the sublist. (This case corresponds to the D channel having been found busy in the multi-site protocol; see 3.4.1.6.5.3.5, item (f).)

If the state value is "inactive" and no downlink ELM entry is present, the D request is new, and the required action shall be to change the state value to "D pending, normal" if USF=0, or to "D pending, multisite" if USF=1, and to generate a downlink ELM entry and insert it at the end of the ELM sublist. This entry contains the data fields specified in 3.4.7.2.4.4.2. It shall contain the following data:

- (a) Sender ID = all zeroes
- (b) Message No. = all zeroes

- (c) Time to expiration = 63 (no expiration)*
- (d) Length = contents of DR minus 15
- (e) Remaining length = length
- (f) Entry indicator
- (g) Reply type code (RC) = 11
- (h) Segment number (NC) = 0000
- (i) Segment request (MC) = a field of N ones followed by (16-N) zeroes, where N = length, in the first 16 bits of MC (subfield SRS); zeroes in the rest of MC
- (j) Completion indicator = incomplete
- (k) Downlink text (MD fields), N 80-bit fields initially set to all zeroes. These fields, if desirable for efficiency, may consist of pointers to the stored text data when available, rather than the 80-bit text fields themselves.

* As an alternative to no expiration, an expiration of 255 scans decremented normally, may be implemented as "no expiration".

An exception to this procedure for a new D request shall take place if a) the unconnected sensor flag USF=1 (indicating use of the multisite protocol); b) UMF=0, c) the subfield IDS=3 in the UM field; and d) the subfield IIS in UM contains a non-zero value which does not equal the local sensor ID. These conditions define a downlink ELM which is directed to another sensor, and the response shall be to ignore the D request and take no action.

3.4.7.3.4.3 Comm-B message data (MB). - Every Comm-B reply contains a 56-bit field MB, which in turn contains a message definition code subfield. The transaction record for the reply will contain an entry indicator so that the MB data may be associated with the proper entry in the Comm-B sublist. Special values of entry indicator ("pilot", "broadcast", and "linked") shall be reserved to indicate a Comm-B reply which was initially detected by the transaction update function of channel management (other than a TCAS message) and hence it shall be determined if it is to be entered in the Comm-B sublist. If the reply carries the entry indicator "linked", the procedures of 3.4.7.3.4.3.3 shall be executed and the remaining procedures of this paragraph omitted. If that entry is a ground-initiated request for downlink data, the response shall first consist of setting the completion indicator in the proper Comm-B sublist entry to one. Next, an output message shall be generated and placed in the output buffer. This message is a ground-initiated downlink as specified in 3.4.7.3.3.1, with the user ID field set equal to the sender ID code. If the Comm-B reply is a pilot message (as indicated by a "pilot" entry indicator code) and the Comm-B state is not "B-busy", the procedures shall be the same except that the output message shall be of the type pilot downlink (with SC set to 00), and that it shall be determined if there is no entry and hence no completion indicator is to be set. If the reply is a pilot message and the B-busy flag is set, no output message shall be generated; the only actions shall be to set the completion indicator (if an entry is present) and to change the Comm-B state to "inactive". If the reply is a broadcast message, an output message of the type broadcast downlink shall be generated and the completion indicator shall be set (if an entry is present). Exceptions to these procedures are defined in 3.4.7.3.4.3.1 and 3.4.7.3.4.3.4.

3.4.7.3.4.3.1 Extended Capability Comm-B.- A ground-initiated Comm-B reply having the values BDS1=0001 and BDS2=0000 in its sublist entry or a broadcast reply containing the same value in the first eight bits of MB is an extended capability reply. The remaining 48 bits of MB contain the extended capability ECA. For a reply of this type, the corresponding completion indicator in the Comm-B sublist shall be set to one, but no ground-initiated or broadcast downlink message issued. Instead the value of ECA in the message shall be compared with the ECA value already present in the surveillance file. If the values differ, the following actions shall proceed:

- (a) The new ECA value shall be entered in the surveillance file.
- (b) An output message of the type data link capability shall be generated and placed in the output buffer. It shall contain the following data, as specified in 3.4.7.3.3.1:

User ID - all zeroes
Mode S address
Capability data - values in surveillance file

- (c) If the reply is a broadcast Comm-B, there shall be no further action. Otherwise, the CAP flag shall be reset.

If the ECA values are the same, the procedures of a) and b) above shall be omitted and those of c) shall be executed.

If a reply containing ECA is received, the "new roll-call target" flag in the surveillance file (3.4.8.7.3.3) shall be read. If this flag is not set, there shall be no further action. If the flag is set, the "flight identification bit" of ECA shall be examined (defined as bit 65 of the Comm-B reply containing extended capability). If this bit is not set, there shall be no further action. If this bit is set, a ground-initiated entry shall be made in the Comm-B sublist containing the following data:

- a) Sender ID - all zeroes
- b) Message number - all zeroes
- c) Time to expiration - 8 scans
- d) Priority - high
- e) BDS1 - 0010, BDS2 - 0000
- f) Completion indicator - incomplete
- g) Entry indicator - ground-initiated
- h) Message data - all zeroes

In either case, the "new roll-call target" flag shall be reset in the surveillance file.

3.4.7.3.4.3.2 TCAS Comm-B.- A Comm-B message resulting from a TCAS request is identified by the reply request code RR-19 in the transaction record or for entry indicator - TCAS in the transaction record. For such a message there is no entry in the Comm-B sublist and hence no completion indicator. The response shall be to generate and place in the output buffer an output message of the type ground-initiated downlink, with the user ID field set to all zeroes.

3.4.7.3.4.3.3 Linked Comm-B replies.- A linked Comm-B reply is identified by the value "linked" in its entry indicator. A Comm-B sublist entry corresponding to a linked reply shall be present only if part of the linked message was received on a previous scan. Processing shall be performed collectively for all received linked replies.

If the last received reply completes the linked message, an output message of the type pilot downlink shall be generated and placed in the output buffer. This message shall have the user ID field set to all zeroes and the segment count (SC) set to one less than the number of segments comprising the linked message. The message data shall include the MB field of each segment in the order received, as contained in Comm-B sublist entries (for segments received on previous scans) and in current replies. Following generation of the message, any corresponding sublist entries, including an initial entry still labeled "pilot", shall be deleted.

If the last received reply does not complete the message, but corresponding entries are present in the Comm-B sublist, the only action shall be to store the MB data from each reply in the appropriate entry and to mark its completion. No entries shall be deleted.

This page intentionally unused.

If the last received reply does not complete the message and corresponding entries are not present in the Comm-B sublist, a new sublist entry shall be appended to the sublist for each segment, whether or not received. Each entry shall contain the following data:

- (a) Sender ID - all zeros
- (b) Message number - all zeros
- (c) Time to expiration - 63 (no expiration)*
- (d) Priority - standard (P = 0000)
- (e) Comm-B definition (BDS): to all zeroes, for an initial segment; according to the rules in 3.4.1.6.5.3.8(b) for remaining segments.
- (f) Completion indicator shall be set to "complete" for an entry corresponding to a received reply; otherwise, to "incomplete"
- (g) Entry indicator - "linked"
- (h) Message data (MB) shall contain the MB data from the corresponding reply for completed entries; otherwise, to all zeroes.

* As an alternative to no expiration, an expiration of 255 scans decremented normally, may be implemented as "no expiration".

In addition, if a "pilot" entry is present in the Comm-B sublist, its completion indicator shall be set.

3.4.7.3.4.3.4 Flight ID Comm-B. - A ground-initiated Comm-B reply having the values BDS1-0010 and BDS2-0000 in its sublist entry or a broadcast reply containing these same values in the first eight bits of MB is a flight ID reply. For either of these cases, the value of flight ID in MB shall be compared with that stored in the Flight ID field of the surveillance field. If the values are the same, no output message shall result. If the values differ, the MB value shall be stored in the surveillance file field and the output message (either ground-initiated downlink or broadcast downlink) shall be issued.

3.4.7.3.4.4 ELM replies. - For ELM transactions, the transaction record shall contain a type code identifying the associated reply (or replies) as being one of two types, as specified in 3.4.7.3.2.2. The response to ELM replies are specified separately by type:

- (a) Uplink ELM replies - For uplink ELM transactions, a tag in the transaction record shall identify the last reply received, as distinguished from earlier replies within the scan belonging to the same transaction (3.4.7.3.2.2). All replies, except the last one, shall be ignored. Within this reply, there are three data fields: KE, ND, and MD, as defined in the Mode S National Standard. For this transaction type KE has the value "1" and ND shall be ignored. The TAS subfield of the MD field shall be read as a cumulative technical acknowledgment from the transponder. A "1" in Nth bit position of this field signifies completion of the segment numbered N-1. The only task of the processor at this time is to transfer this completion information to the appropriate ELM sublist entries. The entry indicator in the transaction record shall identify the proper uplink ELM. Those segments indicated as completed by the cumulative technical acknowledgment data shall have their completion indicators set.

- (b) Downlink ELM replies - For ELM transactions whose types are downlink ELM, there shall be one or more replies referenced. Each reply shall carry a segment of the ELM, with the segment number in ND and the text data in the 80-bit MD field. (KE shall have the value "0".) The entry indicator in the transaction record shall indicate the downlink ELM entry in the ELM sublist. There, the MD data shall be stored, with the ND number indicating the proper segment. No further actions shall be taken if the segment received does not complete the downlink message. If it does, the completion indicator shall be set to one in the ELM sublist entry and an output message shall be generated and placed in the output buffer. This message shall be an ELM downlink message as specified in 3.4.7.3.3.1. The user ID field in that message shall contain "all zeroes."

3.4.7.3.4.5 Active message list updating. - Once per scan per target, it is necessary to perform housekeeping tasks on all sublists of the active message list. It is advantageous to perform the file management tasks immediately after the reply-based processing, so that all output message processing tasks relating to one target are performed in a single sequence. The required tasks consist of deletion of completed or expired entries, generation of delivery notices to the senders, and setting up downlink ELM, clear Comm-C or clear Comm-D transactions. The details vary with the type of transaction involved, and hence are given separately for each case as listed below. Where an expiration of 63 (no expiration) is used, as an alternative, an expiration of 255 scans decremented normally, may be implemented as no expiration.

- (a) Comm-A sublist - For each message in the Comm-A sublist which is tagged as completed, an uplink message delivery notice (3.4.7.3.3.1) shall be generated and placed in the output message buffer. In this message, the user ID field shall be set equal to the sender ID of the Comm-A message, and the DI tag is set to indicate "Delivered." Completed entries shall be deleted from the sublist. The time to expiration field of each incompleted entry shall be decreased by one scan unless the field value is 63 (no expiration). For each message whose time to expiration is now equal to zero, an uplink message delivery notice shall be generated and placed in the output message delivery notice shall be generated and placed in the output message buffer as before, but with the DI tag set to indicate "Expired." Expired entries shall be deleted from the sublist. For the case of a linked Comm-A message which is either completed or expired, a delivery notice shall be sent for the final segment only; previous segments shall be simply deleted. If a partially completed linked message is present, it shall be permissible to change its priority to the maximum value, in order to achieve the ordering rule in 3.4.7.2.4.5. If no entries remain after these deletions, the sublist shall be deleted by appropriate rewriting of pointers.
- (b) Comm-B sublist - The procedures for this sublist shall begin as for the Comm-A sublist, with these distinctions: no entries for partially completed linked messages shall be deleted, notices of successful completion shall not be sent, and notices of expiration shall be sent only for those messages which are ground-initiated. If the current sensor status is not primary, the Comm-B state shall be set to "inactive" and any air-initiated transactions and linked Comm-B transactions shall be deleted from the sublist. If after

deletion of completed and expired messages, there is no entry that is a pilot or linked entry, the "Comm-B state" in the active message file shall be checked. (This field shall have been updated as specified in 3.4.7.3.4, item (c).) If the state is "B pending, normal" or "B pending, multisite", a new entry in the Comm-B sublist shall be made, with sender ID set to "all zeroes" and entry indicator set to "pilot" to indicate an air-initiated message. Also, in this entry, time to expiration shall be set to 63 (no expiration), priority to "standard" (P-0000), Comm-B definition (BDS) to "all zeros", and completion indicator to "incomplete".

- (c) ELM sublist, uplink message - If the current sensor status is not primary, and the Comm-C state value does not equal "C pending, multisite", the only action shall be to delete all uplink ELM entries and set the Comm-C state to "inactive". Otherwise, the following actions shall proceed: If an uplink ELM is in progress, some of the segments may be tagged as completed. If some entries (but not all) remain incompleted, their RC codes shall be updated so that they constitute a proper continuation of the ELM, with a downlink reply requested to the last uncompleted segment, as specified in the Mode S National Standard. If any or all messages remain incompleted, the time to expiration of each message shall be decreased by one scan unless the field value is 63 (no expiration). If this field is then zero for any message, the message shall be deleted, with the generation of an uplink delivery notice indicating expiration. If all segments of an entry have been delivered, the entry shall be deleted. If this entry is the final entry for a message, an uplink delivery notice shall be generated indicating successful delivery. If the first entry in the sublist has been deleted, the Comm-C state value shall be changed from "C pending, normal" to "clear C pending, normal" or from "C pending, multisite" to "Clear C pending, multisite". If after deletions, an uplink ELM message is present with at least one segment completed, it shall be permissible to change the priority of the entire message to the maximum value, to achieve the ordering rule in 3.4.7.2.4.5.
- (d) ELM sublist, downlink message - If the current sensor status is not primary, the only action shall be to delete any downlink ELM entry and set the Comm-D state to "inactive". Otherwise, the following actions shall proceed: If the completion indicator for the message is zero, the time to expiration shall be decreased by one scan unless the field value is 63 (no expiration). If this field is then not zero, the SRS subfield of the MC field shall be updated so that the first N bits contain zeroes in the positions corresponding to the received segments and ones elsewhere, where N is the total number of segments in the message. The remaining length field shall also be updated to indicate the number of segments remaining to be delivered. If the time to expiration has reached zero or if the completion indicator indicates that delivery has been accomplished, the remaining actions shall be to delete the message and to change the Comm-D state value from "D pending, normal" to "clear D pending, normal" or from "D pending, multisite" to "Clear D pending, multisite".
- (e) If the current sensor status is not primary, the Comm-C and Comm-D state values shall be set to "inactive" except that the Comm-C state shall not be changed if it has the value "C pending, multisite". If, after deletions, no entries remain, the ELM sublist may be deleted by appropriate rewriting of pointers.

- (f) If the Comm-C state is "inactive" but one or more uplink ELM entries remain, the state shall be changed to "C pending, normal" or "C pending, multisite", according to the value of USF. If, in this case, one or more segments of an uplink ELM are already marked as completed, their completion indicators shall all be reset to indicate "incomplete", and their RC codes shall be changed so that the entire ELM shall be re-initialized on the next scan. (This case corresponds to the situation in which the Comm-C channel has been found busy in the multisite protocol mode (3.4.1.6.5.3.5, (e)) and some segments has been previously delivered using the normal mode (3.4.1.3.4.3, (h)).

However, if the "no communications" flag is set (3.4.10.3.5.8), items (b) through (e) above shall be interpreted as if the current sensor status is not primary.

Finally, the control block of the active message list shall be updated as required. If all sublists have been deleted, then the control block may also be deleted and the pointer to it in the surveillance file erased, unless the control block still contains useful information about data-link activity (such as comm state values other than "inactive").

This space intentionally unused.

3.4.8 Network management.

3.4.8.1 Purpose and overview.- The purpose of network management is to ensure adequate surveillance and communication for areas of common coverage. Sensors shall coordinate by:

- (a) Maintaining a dynamic map of coverage responsibility based on the "status" of all sensors having coverage overlap.
- (b) Providing for continuity in surveillance over coverage boundaries. This shall be done, for Mode S targets, by providing track data to a newly covering connected sensor until roll-call is successfully established. For a non-connected sensor, it shall be done by appropriate management of transponder lockout to all-call interrogations or the use of the transponder multisite features.
- (c) Providing backup track data to requesting connected sensors on Mode S and ATCRBS targets.

Data links between connected sensors shall be implemented using the sensor/ATC communication links, with relaying of messages at the ATC facility.

Network management shall handle both Mode S and ATCRBS reports, but shall not handle radar reports. For clarity of presentation, the processing of Mode S and ATCRBS reports is specified separately. Sections 3.4.8.2 through 3.4.8.10 are for Mode S; Section 3.4.8.11 is for ATCRBS.

All network management decisions shall be based on information stored in the surveillance file, especially, the network management lists (3.4.8.2) and the coverage map (3.4.8.3). These decisions shall be triggered by one of three basic stimuli: (a) surveillance boundary crossings (3.4.8.6); (b) changes in track quality (3.4.8.7); or (c) reception of network control messages (3.4.8.4 and 3.4.8.8). A network management decision affecting an adjacent connected sensor will generally result in a sensor control message being issued to that sensor (3.4.8.4 to 3.4.8.10). Messages from adjacent connected sensors and ATC or non-ATC facilities to the local sensor are received by the ground communications interfaces and then by the message routing management function (3.4.8.12) which distributes the messages to all major sensor subsystems, such as network management. Message routing management also determines the dissemination of outgoing messages.

Figure 3.4.8-1 is a block diagram of the tasks performed by the network management function other than message routing management. As shown, some tasks shall be performed once a scan on each target in the sector (3.4.6.1.1.4) following its acquisition, others when need arises, as determined by routine checking tasks. Other tasks, such as reacting to incoming network control messages related to any Mode S target shall be performed, as required, several times a scan.

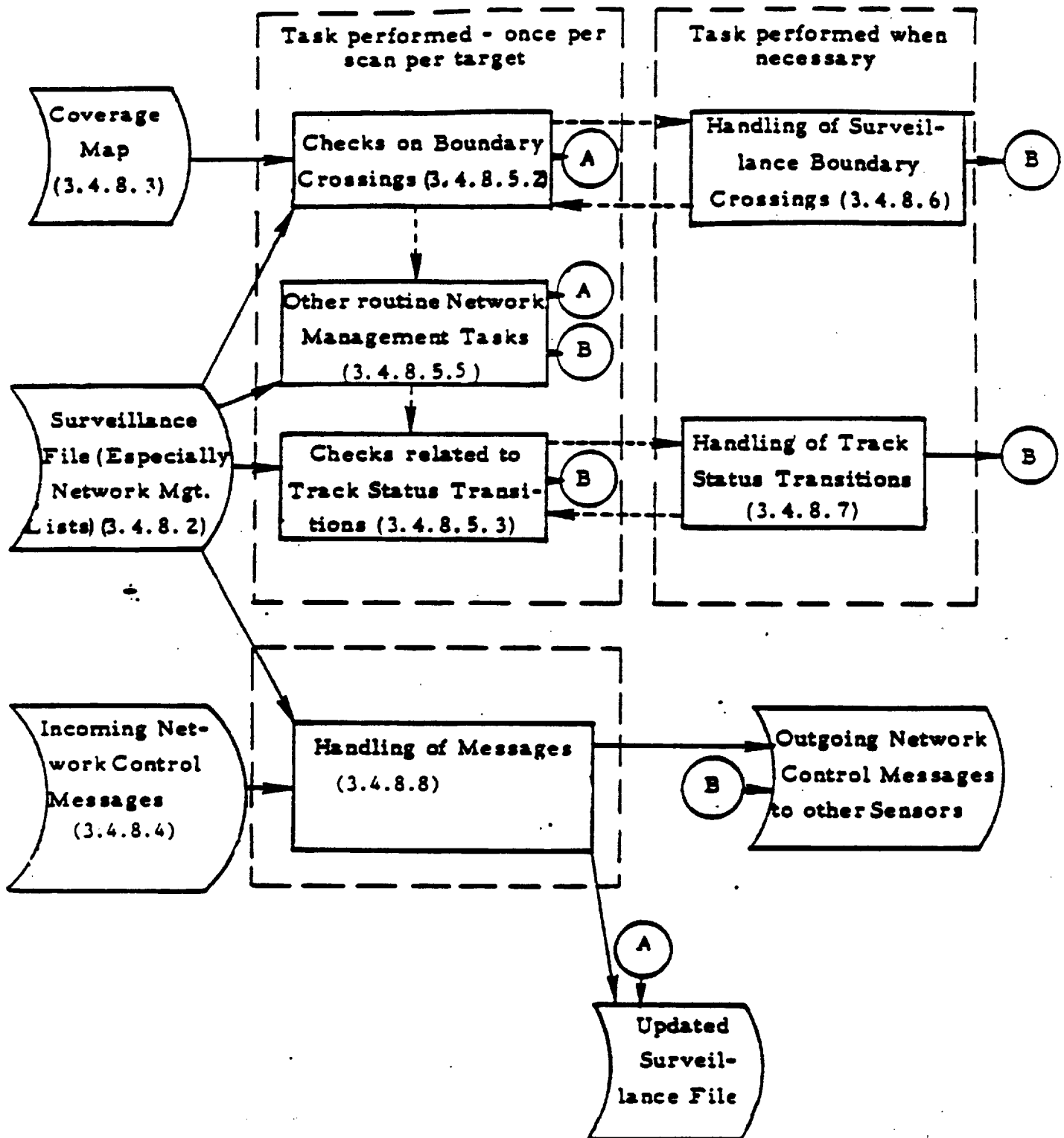


FIGURE 3.4.8-1

NETWORK MANAGEMENT TASKS - BLOCK DIAGRAM

3.4.8.2 Network management lists.

3.4.8.2.1 Definition. - The network management lists contain information for each Mode S target and are used primarily by the network management function. For ease of description and reference, the fields of information are grouped as lists and will be referred to as the target status list, the in-list, the out-list and the network management output list. Physically, these lists shall be part of the surveillance file. The way that this information shall be used is specified in 3.4.8.5 through 3.4.8.9.

3.4.8.2.2 Target status list. - This list shall contain the following information elements for every Mode S target in the surveillance file.

- (a) S: The "track status", defined as a three-bit variable, represents five track conditions needed for network management decisions. The track status categories shall be:

S4: When the track is maintained successfully on local roll-call and fewer than N successive report misses have occurred, when $N = 1$ (1-5, 1).

S3: When the track is exclusively maintained on position reports received from an adjacent sensor.

S2: When the track is in the All-Call mode.

S1: When N or more successive report misses have occurred (the local track was coasted N or more times) while no external position reports are being received.

S0: Is a transitional status used at track initiation.

- (b) PS: A one-bit field representing the "priority-status" of the local sensor with respect to the Mode S target. The priority-status values are:

P: The local sensor is assigned "primary".

S: The local sensor is assigned "secondary" as opposed to primary.

- (c) UC: A one-bit field representing the control status of the target. The control status values are.

U=uncontrolled

C=Controlled.

- (d) Request bits (TR, TRR and IR) for the local sensor - the setting of these bits shall signify whether the local sensor has requested

position data on the Mode S target from adjacent connected sensors. TR=1 shall indicate the data was requested because the local track quality had deteriorated. TRR=1 indicates that the request was issued in anticipation of a fade in the zenith cone. IR=1 indicates the request for external data was issued on demand from a user of netted surveillance data.

- (e) Adjacent assigned sensors - this entry shall list the sensor ID's of the adjacent sensors currently having responsibility for coverage of the given Mode S target as was specified by the local coverage map. For each sensor, it shall also indicate whether that sensor is currently connected or non-connected.

Adjacent sensor IDs as used here and in other network management lists (including the coverage map) shall be coded in a 4-bit field. The sensor shall maintain a table of correspondences between these codes and the 10-bit sensor addresses used in external communications.

- (f) Request bit (RR) for each of the adjacent assigned sensors - the function of request bit RR shall be to indicate that a request for track data was received by the local sensor from the adjacent assigned sensor.
- (g) Coverage map cell index (truncated to 8 least significant bits) - the purpose of this entry shall be to record the current cell index and thus allow detection of cell index changes when matched against the cell index on the next scan (3.4.8.3 and 3.4.8.5.2).
- (h) Special mode flag - the purpose shall be to define the mode in which the coverage map is being used for a given Mode S target (3.4.8.3.4.4).
- (i) Mode S lockout management parameter (DLM) - The current value of the Mode S coverage map parameter for this target (3.4.8.3.4.3).
- (j) Target Lockout Control State (LCS). There are three values:
 - Fully locked
 - Fully unlocked
 - Intermittent lockout.
- (k) Lock Count (LC). This parameter expresses the number of scans since the beginning of a current lock period. LC is ignored if the Mode S lockout bit, DL, equals 0 (3.4.8.2.5).
- (l) Unlock Count (ULC). This parameter expresses the number of scans since the beginning of a current unlock period. ULC is ignored if DL=1 (3.4.8.2.5).
- (m) All-Call Flag (AF). This parameter, set by surveillance processing, expresses the observed lockout state of the target transponder on the current scan. AF is set to 1 if one or more valid all-call replies were received during the scan. Otherwise, AF is set to 0.

- (n) All-Call Count (AC). This parameter gives the current number of scans for which AF = 1.
- (o) Coordination in Progress Flag (CIP). A setting equal to one shall signify that the local sensor is executing the handoff protocol specified in 3.4.8.3.5.4.
- (p) Capability Request Flag (CAP). This parameter is set to indicate the need to interrogate an aircraft to determine its extended data link capability. It is set by network management whenever an aircraft enters full track, and may also be set by data link processing.
- (q) New ELM target flag. This parameter, when set to one, indicates that uplink ELM delivery to the target has not been attempted since the sensor became primary. It is used by data link processing to cause clearing of the Comm-C channel before the first such ELM delivery. (3.4.7.2.5.4).
- (r) Radar zenith cone flag (RZC). This flag indicates whether the target is in the zenith cone of the primary radar and hence whether radar substitution should be attempted (3.4.8.5.2 and Appendix IV, 3.3.4.1).
- (s) New roll-call target flag. This flag is set whenever a target enters the track state S4. It is used by data link processing in connection with readout of aircraft variable flight ID.

Of these parameters, the four items (k) through (n) are interpreted only for those targets whose current lockout control state is intermittent lockout.

3.4.8.2.3 In-list. The in-list for each Mode S target record in the surveillance file shall contain the ID of the sensor from which track data are being received and a one-bit flag (symbol IF). Flag IF shall be set equal to one if track data received are actually sent to the Mode S track data message processing (3.4.6.11) for insertion in the local surveillance file. Flag IF shall be set equal to zero if the track data received are suppressed (this would occur when track data from another adjacent sensor are already being used).

3.4.8.2.4 Out-list. The out-list for each Mode S target record in the surveillance file shall contain:

- (a) The ID of the sensor(s) to which track data are being sent by the local sensor.
- (b) A one-bit indicator (symbol OSE) to flag an entry of the out-list that is temporarily not being serviced. The ensemble of entries in the out-list for which OSE is set equal to one will be further referred to as the request outstanding list.

- (c) A three-bit expiration counter (OEC) which causes the entry in the request outstanding list (OSE set) to be erased when the number of scans counted by OEC exceeds its threshold value (OECT = 5 (2-7, 1)).

3.4.8.2.5 Network management output list.- This list shall be a part of each Mode S track record in the surveillance file that groups elements that are specified outputs of the network management function. They are used by other system functions such as channel management and data link processing. They are:

- (a) The Mode S lockout bit (DL). The setting of this bit to one indicates that the Mode S transponder must be locked out for combined ATCRBS/Mode S all-call and Mode S-only all-call interrogations.
- (b) Unconnected sensor flag (USF). If any sensor listed as an adjacent assigned sensor is currently unconnected to the local sensor, and if the target is uncontrolled (UC=U), this one-bit flag shall be set. USF is used by channel management (3.4.1.3.4.3) and by data link processing (3.4.7.2.5.4, 3.4.7.3.4.2) to determine whether "normal" or "multisite" protocols shall be used in data link transactions.
- (c) Connected sensor flag (CSF). If any sensor listed as an adjacent assigned sensor is currently connected to the local sensor, this one-bit flag shall be set. CSF is used in sensor priority status determination (3.4.8.3.5.3).

3.4.8.2.6 Summary table.- Table 3.4.8-1 presents a summary of network management list components. Additional items, which are used exclusively by network management, may be required.

3.4.8.3 Coverage map.

3.4.8.3.1 Definition and purpose.- The coverage map shall be a file. It shall contain the information from which the coverage responsibility of the local and adjacent sensors can be established. It shall also contain some parameter values which are a function of the map position and which are used as decision variables by channel management, data-link processing, or network management in determining whether or not to perform specific tasks.

3.4.8.3.2 The coverage map to be used at each site.- The coverage map shall be site-specific. Assignment of coverage to certain sensors over a given area will usually follow the rule of proximity. However, ATC surveillance requirements, special topographic conditions and existence of obstructions may change that rule. The data corresponding to the general description of the map, as given in 3.4.8.3.3, will be provided to the contractor for each site. The contractor, however, shall be responsible for transforming that description into a coverage map file for the computer, as described in 3.4.8.3.4.

TABLE 3.4.8-1SUMMARY TABLE

<u>List Name</u>	<u>Component</u>	<u>Symbol</u>	<u>Number of bits</u>
Target Status List	Target Track Status	S	3
	Sensor Priority Status	PS	1
	Control Status	UC	1
	Request bit	TR, TRR	2
	Netted Surveillance User		
	Request Bit	IR	1
	*First Adjacent Assigned		
	Sensor	Sensor ID	4
	*Its Connectivity Flag	--	1
	*Its Request bit	RR	1
	Coverage Map Cell Index		
	(last 8 bits)	IQ	8
	Special Mode Flag	SMF	1
	Mode S Lockout		
	Management Parameter	DLM	2
	Lockout Control State	LCS	2
	Lock Count	LC	5
	Unlock Count	ULC	6
	All-Call Flag	AF	1
	All-Call Count	AC	6
	Coordination in Progress	CIP	1
	Capability Request flag	CAP	1
	New ELM Target Flag	--	1
	Radar Zenith Cone Flag	RZC	1
	New Roll-call Target Flag	--	1
In-List	*First Sensor ID	Sensor ID	4
	*Flag for active use	IF	1
Out-List	*First Sensor ID	Sensor ID	4
	Flag to suspend action on		
	this target	OSE	1
	Expiration Counter	OEC	3
Network Mgt. Output List	Mode S Lockout bit	DL	1
	Unconnected Sensor Flag	USF	1
	Connected Sensor Flag	CSF	1

*Repeated for each additional sensor as needed.

3.4.8.3.3 General description of the coverage map.- The total volume of airspace which a sensor may possibly cover is divided into three zones. The inner zone, closest to the sensor, is the required zone, where the local sensor shall be required to provide coverage. Such a sensor is said to be assigned. Surrounding the required zone is the permitted zone to which a sensor may extend coverage only under special circumstances (3.4.8.6). The permitted zone, in turn, is surrounded by the forbidden zone where the sensor shall never cover a target.

The basic information given the contractor for the map is defined in FAA-RD-82-37.

3.4.8.3.4 Description of the coverage map file.

3.4.8.3.4.1 Discretization of the map.- The area of coverage for which information shall be stored is the area made up by the required and permitted zones of the local sensor. To facilitate this storage of information, the area of interest shall be divided into elementary areas, called cells, by overlaying it with a regular grid structure (fig. 3.4.8-2). This grid is characterized by the following range and azimuth increments:

Range increments: $64 \mu s (2^{10} Ru)$ for range less than $2^{10} \mu s (2^{14} Ru)$

$128 \mu s (2^{11} Ru)$ for range over $2^{10} \mu s (2^{14} Ru)$

Azimuth increments: $360^\circ (2^{14} Au)$ for a range less than $2^6 \mu s (2^{10} Ru)$

$22.5^\circ (2^{10} Au)$ for a range between 2^6 and $2^8 \mu s$
(2^{10} and $2^{12} Ru$)

$11.25^\circ (2^9 Au)$ for a range between 2^8 and $2^9 \mu s$
(2^{12} and $2^{13} Ru$)

$5.625^\circ (2^8 Au)$ for a range over $2^9 \mu s (2^{13} Ru)$

The maximum range shall be $3200 \mu s (= 258.8 \text{ nmi})$ which implies a maximum number of 1777 cells. The range up to which the grid pattern is implemented at each site shall equal the smallest quantized range of the grid greater than the maximum range (over all azimuths) used to describe the permitted zone of the local sensor. The number of cells to be used for the coverage map is then determined by that range. For clarity of description, the following terms are introduced and shall be understood as defined herein:

- (a) "Subarea". A subarea is the smallest area for which each cell belongs to the required and permitted zone of the same set of sensors listed with the same priority.

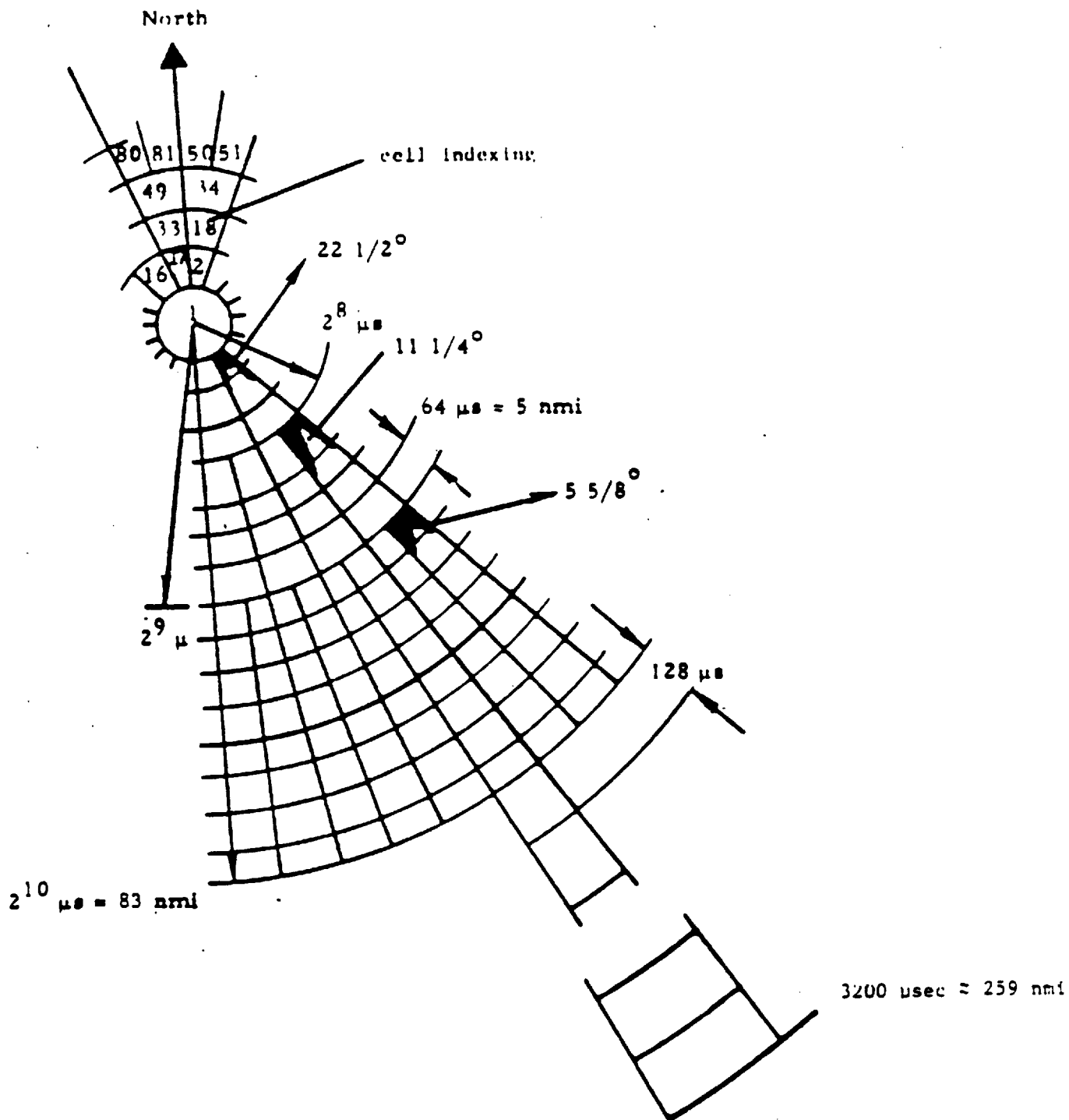


FIGURE 3.4.8-2
GRID STRUCTURE

- (b) "Altitude-breakpoint". An altitude-breakpoint associated with a given sensor is the altitude approximating the line-of-sight cutoff in the sensor in the given cell of the coverage map.
- (c) "Primary sensor". The coverage map lists a particular sensor as the best sensor (usually based on proximity) to use for surveillance and data-link service. Such a sensor will be referred to as the primary sensor (3.4.8.3.5) and the collection of cells where the sensor is listed first in the subarea list is called the primary zone.

The rules that shall be adhered to when developing the coverage map for a particular sensor are given in FAA-RD-82-37.

3.4.8.3.4.2 Contents for each cell.- For each cell, the map shall specify:

- (a) A pointer to a list of sensors for the subarea to which the cell belongs. The sensors shall be listed in the correct order of priority. Each adjacent sensor shall be tagged as being either connected or non-connected. The maximum number of sensors to be listed for any subarea shall be a parameter $N = 3$ (1-8,1).
- (b) An altitude breakpoint for each sensor listed.
- (c) A set of flags.
- (d) The value of parameter MNAS (3.4.8.3.4.4) reflecting the desired multiplicity of coverage.

This information may be stored in the form of two lists:

- (a) The cell content list.
- (b) The subarea list.

The meaning of the several fields is explained in Table 3.4.8-2.

3.4.8.3.4.3 Mode S lockout management parameter.- The Mode S lockout management parameter (DLM) is not contained in the coverage map file, but is a target status parameter based in part on coverage map data. There are three states of this parameter to be expressed:

Full lockout
Intermittent lockout
Temporary intermittent lockout.

The first two of these states shall be assigned to aircraft located in a particular map cell, according to the following rules:

TABLE 3.4.8-2DEFINITION OF COMPONENTS OF THE COVERAGE MAP.

<u>Component</u>	<u>No. of Bits</u>
The value of MNAS for this cell.	3 bits
A pointer to an entry in a short list of N sensors for each subarea.	5 bits
Altitude breakpoints for the sensors listed in the subarea list. Value range (500 - 50,000, 500) feet.	N x 7 bits*
Primary Flag, to indicate whether the local sensor is the primary sensor on the map.	1 bit
Zenith Cone Flag, to flag proximity to the site.	1 bit
Sensor ID's	N x 4 bits*
Connected sensor flags - For each sensor ID listed, an indication whether it has a ground communication link to the local sensor.	N x 1 bit *

*Repeated for each sensor in the subarea.

- (a) If there are no adjacent Mode S sensors assigned, the state shall be full lockout.
- (b) If all of the assigned sensors are connected, the state shall be full lockout.
- (c) If the site addressed lockout mode is in use, the state shall be full lockout.
- (d) If the site-addressed lockout mode is not in use and if there is at least one non-connected sensor assigned, the state shall be intermittent lockout.

The third state, temporary intermittent lockout, may only occur as a result of processing certain performance monitor inputs. Performance monitoring shall make a determination of "sensor communications failure/ recovery" status for each connected sensor (3.4.10.3.4.2). (This is in addition to the determination of sensor failure/recovery which is used to set the special mode flag). A change in this status has the following effect on the values of DLM:

- (a) Communications failure: If the state is "full lockout" and site-addressed lockout is not in use, it shall be changed to "temporary intermittent lockout" for Mode S targets in the cells where the affected sensor is assigned. Otherwise, there shall be no effect.
- (b) Communications recovery: If the state is "temporary intermittent lockout", it shall be changed to "full lockout" for Mode S targets in the cells where the affected sensor is assigned. Otherwise, there shall be no effect.

DLM shall be initially defined for a target when it enters track status S4. A change in DLM state shall be flagged so that when routine network management tasks are performed on a Mode S target, the change shall be handled as if the target had crossed a cell boundary (3.4.8.5.4.2). For each Mode S target, the value of DLM to be used in setting lockout shall be updated whenever the target crosses a cell boundary. In order to recognize a change in DLM value, the current value of DLM shall be stored in the target status list. An additional dynamic flag may be defined to indicate a current change in DLM.

3.4.8.3.4.4 Use of the coverage map. - The coverage map is read for certain fields of information relevant for a Mode S target in a given position. The distinction between a required and permitted area lies in the number of sensors that will be read from the map, in normal operating conditions. This number, MNAS = 2 (1-5, 1), reflects the desired multiplicity of coverage provided by adjacent sensors and is implicit in the extent of the required areas for these sensors. In normal operating conditions, the first MNAS sensors (if available) will be read out of the map. This way of using the map will be further referred to as the "normal mode". If an adjacent sensor has

failed, the performance monitoring function will provide the ID of that sensor. The algorithm reading the map shall be designed to read the first MNAS sensors (if available), ignoring all data such as ID and altitude breakpoint relating to the failed sensor. This way of reading the map will be referred to as the "special mode" and will be indicated by setting a special flag equal to one.

The steps necessary to define which sensors are designated by the map to provide coverage are now outlined. The sensors so designated will be referred to as "assigned sensors".

- (a) The first step shall be to calculate the index of the cell, given the target position (p , θ , H). An algorithm that may be used is specified in Table 3.4.8-3.
- (b) The special mode flag (SMF) shall be read.
- (c) The next step shall be to compare the cell index and SMF with the corresponding values found on the previous scan and stored in the target status list of the surveillance file (3.4.8.2.2). If no change occurred, and if the failure/recovery state of any listed adjacent sensor has not changed since the previous scan, the information read from the map on a previous scan is still valid and no further action is needed. Otherwise, the steps described below shall be executed.
- (d) Read the first MNAS sensors, if present, while ignoring any sensor that has failed if the map is being used in the special mode.
- (e) For all sensors thus read out of the map, other than the first, compare the target altitude H with the altitude breakpoint h of the sensor and retain those sensors for which $H > h$. The first sensor and the sensors thus retained, if any, are further referred to as the "assigned" sensors.

Other tasks to be performed when the cell index or SMF flag changes are specified in 3.4.8.5.2.

3.4.8.3.5 Determination of the sensor priority status.

3.4.8.3.5.1 Purpose and description.— The sensor priority status (symbol PS) shall be a parameter in the data block of each Mode S target in the surveillance file (3.4.8.2.2). This parameter may take on either of two values P (primary) or S (secondary). The PS parameter shall serve as a decision variable for network management in the determination of Mode S lockout status, and for channel management and data-link processing in determining whether or not to perform readout of pilot-originated air-to-ground messages and extended length message delivery. These decisions shall correlate with the PS values as follows: Mode S lockout (whether full or intermittent), readout of

TABLE 3.4.8-3
CALCULATION OF CELL INDEX I.

Let:

ρ and θ represent the measured target position, (16 bits for range in Ru, 14 bits for azimuth in Au).

θ_1 , θ_2 , and θ_3 represent the quantized azimuth-fields made up of the 6, 5, and 4 most significant bits of θ .

X_1 and X_2 represent the quantized range-fields made up of the 5 and 6 most significant bits of ρ .

The Cell Index I shall then be obtained via the algorithm:

If $(X_1 - 8 = Y) > 0$, $I = 64 Y + 690 + \theta_1$.

Otherwise,

if $(X_2 - 8 = Z) > 0$, $I = 64 Z + 178 + \theta_1$.

Otherwise,

if $(X_2 - 4 = R) > 0$, $I = 32 R + 50 + \theta_2$.

Otherwise,

if $(X_2 - 1 = Q) > 0$, $I = 16 Q + 2 + \theta_3$.

Otherwise,

$I = 1$.

pilot-originated Comm-B messages, delivery of Comm-C messages, and readout of pilot-originated Comm-D (ELM) messages shall be provided only if PS=P. Rules for determining PS value shall depend upon the target control state as expressed in the parameter UC of the target status file (3.4.8.2.2). For controlled targets (UC=C), the PS value shall be determined solely from an assignment contained in a message from an ATC facility (3.4.8.3.5.2). For uncontrolled targets (UC=U), the PS value shall be determined from the coverage map (3.4.8.3.5.3) and, in certain cases, by a coordination procedure (3.4.8.3.5.4). For new targets, whose control state is not known, a procedure for assigning both UC and PS is given in 3.4.8.3.5.5.

3.4.8.3.5.2 Controlled target case.- The PS value for a controlled target (UC=C) shall not be changed except upon receipt of a Mode S aircraft control state message from an ATC facility which identifies the particular Mode S target. If such a message assigns the value primary or secondary to the target, its PS value shall be set accordingly and its UC=C shall be retained. If the message assigns the value uncontrolled to the target, UC shall be set to U and the procedure of 3.4.8.3.5.3 shall be followed.

3.4.8.3.5.3 Uncontrolled target case.- The PS value for an uncontrolled target (UC=U) shall be determined by reference to the coverage map. PS shall be assigned P or S according to whether the local sensor is listed as the first sensor (highest priority) for the cell or not. In this determination and in further procedures for assigning primary, any sensor in a current failure condition shall be omitted from consideration. Use of the coverage map to determine PS for a particular uncontrolled target shall be preempted if an aircraft control state message is received which refers to that target. In that event, the procedure of 3.4.8.3.5.2 shall be used to update UC and PS. If such a message assigns UC=C and PS=P, and the CSF flag is set, the special procedure of 3.4.8.3.5.6 shall be executed. In the absence of such a message, PS shall be updated as part of the routine tasks associated with boundary crossings.

In certain cases further procedures shall be followed. These procedures shall be executed whenever both of the following conditions apply:

- (a) a cell boundary crossing has occurred and the PS value for the new map cell differs from the PS value in the target status list.
- (b) the connected sensor flag (CSF) is set.

If both of these conditions apply, the processing continues as specified in 3.4.8.3.5.4. Otherwise, the PS determination is complete.

3.4.8.3.5.4 Coordination procedures.- If the map value is PS=P and the (old) target list value is S, a coordination transaction shall be initiated by setting the coordination in progress flag and sending a primary coordination message to each connected assigned sensor. These messages shall contain the

value "request for primary", which anticipates replies of the same message type. Pending receipt of these replies, PS=S shall be retained. If all replies contain the value "primary assignment approved", PS=P shall be assigned. If any reply contains the value "primary assignment disapproved", PS=S shall be assigned. While replies are pending, a message may be received which contains "request for primary" with respect to the same target. (This could occur in the case of a new track originating in an area of primary overlap on the coverage map.) In this case, the response shall be to send a message containing approval or disapproval according to the value of a site precedence parameter. This parameter shall be a part of site adaptation, and it shall indicate a precedence ordering of all adjacent connected sensors. If, for every adjacent assigned sensor either a) a disapproval has been sent or b) an approval has been received, then PS=P shall be assigned; otherwise, PS=S shall be retained. When PS has been determined according to these rules, the coordination in progress flag shall be reset and the transaction shall be complete, although it may be triggered again when the target crosses another coverage cell boundary.

If the map value is PS=S and the (old) target list value is P, a different coordination transaction shall be initiated. In this case, the coordination in progress flag shall be set and a coordination message with the value "request for secondary" shall be sent to the highest-priority sensor for the cell, provided that sensor is connected. The anticipated response is a message containing the value "primary assignment accepted". If such a response is received, the PS value shall be changed to S. In the absence of such a response, the value P shall be retained. The transaction shall not be repeated until another cell boundary has been crossed. If the highest-priority sensor assigned is not connected, the map value S shall be taken without any coordination attempt. The coordination in progress flag, CIP, shall be reset when PS has been determined according to these rules.

The responses to incoming coordination messages (other than anticipated response messages described above) shall be as follows:

If a message is received with "request for primary", the response shall depend on the track state, PS state, and UC state:

- (a) If the target is unknown (not in the surveillance file), a reply message shall be sent with the value "primary assignment approved".
- (b) If the target is on file but not in track state S_1 , and the coordination in progress flag is not set, PS=S shall be assigned and a reply message shall be sent with the value "primary assignment approved", provided that the target is not controlled primary.
- (c) If the target is in track state S_1 with PS=P, or is in track state not S_1 with PS=P and UC=C, a reply message shall be sent with the value "primary assignment disapproved".

To achieve the durations LD and UD of actual locking and unlocking of the transponder, it is necessary to consider also the time-out period of the lockout state, nominally 18 sec.

T = transponder Mode S lockout time-out, in scans, i.e.

$$T = \frac{18 \text{ sec}}{\text{Sensor scan period, in sec}}$$

(If T is a fraction, the value shall be rounded up to an integer.)

The nominal lockout cycle shall be represented by the following sequence of commands:

Unlock: DL=0 for UD+T scans.
Lock: DL=1 for LD-T scans.

To prevent arbitrarily prolonged lock and unlock periods under non-nominal conditions, the following limiting values shall be used:

Maximum Lock Duration (LDM). $LDM = LD + (2*UD) - 1$ scans.

Maximum Unlock Duration (UDM). $UDM = (UD + LD) * K$ scans,
where K = 1 (1-3, 1).

3.4.8.5.4.4 Intermittent lockout processing.- A target newly assigned to the intermittent control state shall always be initialized by beginning an unlock period: setting DL = 0, unlock count ULC = 1, and all-call count AC = 0.

For other targets in this state, an update shall be performed according to the following rules:

For targets presently in an unlock period (DL = 0), the unlock count ULC shall be incremented by 1. If the count ULC then exceeds the unlock duration maximum UDM, the period shall be ended by initiating a lock period. If the maximum is not exceeded, the all-call flag, AF, shall then be read. If AF = 0, the all-call count AC, shall not be incremented and the processing ends. If AF = 1, AC shall be incremented by 1 and then tested to see if it has reached the nominal unlock duration UD. If AC is less than UD, there shall be no further action and the unlock period shall continue. If AC = UD, the unlock period shall be ended by initiating a lock period. (A lock period shall be initiated by setting DL = 1 and LC = 1).

For targets presently in a lock period (DL = 1), the lock count LC shall be incremented by 1. If the count LC does not exceed the lock duration LD (with allowance for timeout T), no further action shall be taken and the lock period

The area of the required zone is dynamically changeable (3.4.8.3.4.4). The required zone, and hence the ATCRBS/radar range mask corresponding to it, used under normal operating conditions, is part of the general map-description given the contractor. That mask table will be termed standard. For operating conditions during an adjacent sensor failure, the standard required zone (and the mask) is enlarged in an attempt to maintain a constant multiplicity of coverage over the total area for which the Mode S network is responsible. This enlargement is accomplished by reading the sensors from the coverage map in the special mode (3.4.8.3.4.4). As soon as the performance monitoring function declares the failure mode for an adjacent sensor, this special mode shall be adopted and a new mask table shall be set up by the routine described below. This mask table shall then be used as long as the failure persists. The standard mask table shall then be reinstated when normal operations resume.

The routine used to set up the new mask table consists of establishing the range of the (enlarged) required zone of the local sensor for each of 64 azimuth wedges. To do this, the maximum cell index for the given wedge must be determined for which the local sensor is among the MNAS first sensors (ignoring the failed sensor(s)) listed in the coverage map. The outer range of that cell shall be the value entered in the mask table for the given azimuth wedge.

3.4.8.4 Network control messages.

3.4.8.4.1 Description. - Messages exchanged between connected sensors for purposes of network management shall be defined as network control messages. Connected sensors in the network shall cooperate and coordinate their actions through the exchange of network control messages. The specific conditions, triggering message exchange, are the major topic of 3.4.8.5 through 3.4.8.9. This section defines each message and its components. The necessary formats and contents shall be as specified in Table 3.4.8-4.

The table format is read as follows. Message bit numbers represent required field length, and are placed under the message formats. Field bit length are in (...) if required length. Field bit lengths are in (...) if minimum length. Bit numbers, except 1, are left off any messages with the bit length specified this way. Spare (zero) bits and data bits added to fields, may be used for field alignment as long as the average overhead, due to these bits, is not greater than 20 percent.

The typecode assignments for these messages are found in 3.4.8.12.2 and 3.4.8.12.6.3.

The sensor shall maintain a site adaptable table of correspondence between 10 bit adjacent sensor IDs and the ATC communications links. This table shall indicate which ATC communications link is to be used for communications with any given adjacent sensor. Any one adjacent sensor shall be assigned to only one ATC communications link.

3.4.8.4.2 Comprehensive network control message listing. - A first group of messages shall relate to establishing or terminating the flow of track data between sensors. A second group shall consist of a coordination message to establish the sensor priority status (3.4.8.3.5.3) for certain situations. A third group shall relate to the management of exceptional track alert situations. The functional significance of each of these messages shall be as follows:

- (a) A sensor requests data from another sensor by issuing a data request message. The receiving sensor, when able to comply, responds with a data start message which is then followed scan after scan by a track data message. Note that data start and track data messages shall always be based on locally measured data, and shall not be issued if the track was coasted or updated with external data. If the receiving sensor was unable to comply, it would have answered with a data stop message. When the data-requesting sensor no longer requires external track data, it issues a cancel request to which the receiving sensor answers with a data stop.

TABLE 3.4.8-4 (a)

DATA BLOCK FORMATS FOR NETWORK CONTROL MESSAGES

Data Start Message

typecode (8)	MODE S ID (24)	meas. range (16)	meas. azimuth (14)
--------------	----------------	------------------	--------------------

1

range rate (8)	azimuth rate (8)	altitude (12)	time-reference (8)
----------------	------------------	---------------	--------------------

transponder capability, CA (3)	RSID (10)	SSID (10)
--------------------------------	-----------	-----------

Track Data Message

typecode (8)	MODE S ID (24)	meas. range (16)	meas. azimuth (14)
--------------	----------------	------------------	--------------------

1

range rate (8)	azimuth rate (8)	altitude (12)	time-reference (8)
----------------	------------------	---------------	--------------------

transponder capability, CA (3)	RSID (10)	SSID (10)
--------------------------------	-----------	-----------

TABLE 3.4.8.8-4(b)

DATA BLOCK FORMATS FOR NETWORK CONTROL MESSAGES (CON'T)

Data Stop Message

typecode	MODE S ID	RSID	SSID
1 8	9 32	33 42	43 52

Data Request Message

typecode	MODE S ID	RSID	SSID
1 8	9 32	33 42	43 52

Cancel Request Message

typecode	MODE S ID	RSID	SSID
1 8	9 32	33 42	43 52

Primary Coordination Message

typecode	MODE S ID	Value	RSID	SSID
1 8	9 32	33 35	36 45	46 55

Value - Request for Primary
 Primary Assignment Approved
 Primary Assignment Disapproved
 Primary Assignment Accepted
 Request for Secondary
 Controlled Primary Notice

Track Alert Message

typecode	MODE S ID	RSID	SSID
1 8	9 32	33 42	43 52

- (b) The data request/cancel message may also be sent from a user of netted surveillance data to the local sensor to request/cancel request for external data. The network management function shall identify the adjacent sensor which shall receive the data request/cancel message. The track data shall be routed to the requesting user via the local network management function.
- (c) The meaning of the primary coordination message was explained in the context of establishing the sensor priority status (3.4.8.3.5.4).
- (d) The track alert message shall be used to manage the duplicate Mode S address condition.

3.4.8.5 Routine network management tasks.

3.4.8.5.1 Purpose and description.- A series of checks and tasks shall be performed once a scan for each Mode S target. The first check, to be performed on established tracks only, shall be based on the coverage map and shall determine if a surveillance boundary crossing has occurred since the last scan. If a boundary crossing has occurred, the resulting change in sensor assignments shall require further network management activity as specified in 3.4.8.6. A second check shall be designed to detect changes in track quality referred to as target track status transitions (see 3.4.8.2.2(a)). If such a status transition has occurred, further network management activity shall occur as specified in 3.4.8.7. The task of updating Mode S lockout parameters shall be performed as specified in 3.4.8.5.4.

3.4.8.5.2 Checks related to boundary crossings and related tasks.- The following steps shall be executed:

- (a) The next Mode S target shall be selected from the surveillance file. The steps outlined in 3.4.8.3.4.4 shall be followed to determine the current cell index value. If a cell boundary crossing has occurred since the last scan, or if any adjacent sensor listed for the cell has failed or recovered since the last scan, steps (b) and (c) shall be omitted and steps (d) through (i) performed.
- (b) If a Mode S aircraft control state message has been received for the target since the last scan, steps (c), (e), and (f) shall be performed.
- (c) If the zenith cone flag is currently set for the target, step (i) shall be performed. If none of the conditions in (a), (b), or (c) have been met, tasks under 3.4.8.5.2 are ended.
- (d) The set of assigned sensors shall be updated as specified in 3.4.8.3.4.4.

- (e) If the target is uncontrolled (UC=U), the procedures for updating priority status given in 3.4.8.3.5.3 and 3.4.8.3.5.4 shall be followed. If the procedures cause a change from S to P, the New ELM Target flag shall be set to 1.
- (f) The setting of the Mode S lockout control state shall then be updated, according to the procedure of 3.4.8.5.4. If a failure of an adjacent sensor has been declared, the setting of the DL bit is, in addition, subject to the rule described in 3.4.8.6.5. If the target is found to be in a state of persistent track coast, the setting of the DL bit is further subject to the rule described in 3.4.8.5.3, subparagraph (b).
- (g) The set of adjacent assigned sensors, read from the target status list augmented with the local sensor, shall be compared with the set of assigned sensors found in (d) to detect if a sensor has been added or deleted. If this is the case further action, as described in 3.4.8.6, shall be taken.
- (h) The unconnected sensor flag (USF) and the connected sensor flag (CSF) shall be updated according to the current connected/unconnected indicators of the sensors in the updated set of adjacent assigned sensors, and (for USF) according to the current value of UC (3.4.8.2.5).
- (i) The zenith cone flag shall be read from the coverage map. If equal to one and the target has an elevation angle greater than $BE=34$ ($0-90, 2$) degrees, the request bit TRR shall be set to one and a data request issued to adjacent connected assigned sensors (if not already done). If the zenith cone flag is zero or if it is one and the target elevation angle is less than BE, flag TRR shall be set to zero. When TRR is reset from one to zero and the other request bits TR or IR are not equal to one, a cancel request message shall be issued.

If the zenith cone flag is equal to one and the target has an elevation greater than $BE=34$ ($0-90, 2$) degrees, then the radar zenith cone flag RZC shall be set to one. Otherwise, flag RZC shall be set to zero.

3.4.8.5.3 Checks related to target track status transitions.- The following steps shall be executed:

- (a) The reply-type of the last report and the target track status S shall be read from the surveillance file. If $S = S_0$, the reply-type shall be checked. If the type indicates external data, the new state of S_3 is assigned; otherwise, the new state is S_2 .

-313-

- (b) If S = S4, check if the track has coasted for fewer than N consecutive scans where N = 1 (1-5, 1).
If S = S3, check if the reply type indicates external data.
If S = S2, check if the reply-type indicates All-Call.
If S = S1, check if the reply-type indicates missed reply. If this check is positive, the Mode S lockout bit (DL) shall be set to zero in the network management output list.
- (c) If any of the checks in (b) are negative, a state transition has occurred and further actions shall be taken as described in 3.4.8.7.

3.4.8.5.4 Mode S lockout management.

3.4.8.5.4.1 Purpose and description.- The purpose of Mode S lockout management is for the sensor to control the lockout state (with respect to ATCRBS/Mode S or Mode S-only All-Calls) of transponders for which it is assigned primary. This shall be done in such a way that:

- # (a) Full Mode S lock-out (DL=1) shall occur in regions of airspace where no other sensor has surveillance coverage or where coverage is shared only with connected sensors.
- (b) Mode S lockout shall be intermittent in regions where coverage is shared with sensors which are not connected (either permanently or temporarily because of communications failure). #

The determination of which of these two conditions applies is called lockout control state assignment, and the procedure for performing it is given in # 3.4.8.5.4.2. If the site-addressed lockout mode is used, the rules of 3.4.1.5.4.4.1(5) effectively override this procedure. #

Targets in an intermittent lockout control state shall be alternately locked and unlocked. The parameters for a nominal cycle of intermittent lockout are defined in 3.4.8.5.4.3. Departures from the nominal cycle shall occur under the following circumstances:

- (a) A nominal lock period shall be extended to prevent simultaneous unlocking of two nearby aircraft.
- (b) A sequence of nearby aircraft pairs could result in an indefinitely prolonged state of lockout. This low-probability event shall be prevented by putting a maximum on the duration of a lock period.
- (c) A period of unlock commands shall be continued until actual transponder unlocking has occurred (as observed from all-call replies) for the required number of consecutive scans. This procedure prevents two

primary sensors from effectively denying acquisition to a third sensor, by causing their unlock periods to synchronize.

- (d) Since unlock periods are timed by receipt of all-call replies which may be subject to garbling, it would be possible for a transponder to be left in a prolonged unlocked state because valid replies are not received. This situation is handled by putting a maximum on the duration of a period of unlock commands.

The algorithm for performing intermittent lockout in accordance with these rules is given in 3.4.8.5.4.4.

3.4.8.5.4.2 Lockout control state assignment.- During routine processing of a Mode S target (once per scan), lockout control assignment shall be performed if any of these conditions apply:

- (a) The target is newly acquired (transition into state S4).
- (b) The value of the target status parameter Mode S lockout management has changed.
- (c) The primary/secondary status has changed.

If these conditions do not apply, there shall be no further processing unless the target is in an intermittent lockout control state. In that case, processing shall continue with an intermittent update (3.4.8.5.4.4). If a target does qualify under these conditions, lockout control state shall then be assigned according to the following rules:

- (a) If PS = S, the state shall be set to fully unlocked, and DL=0.
- (b) If PS = P and the current lockout management parameter value = full lockout, the state shall be set to fully locked, and DL=1.
- (c) If PS = P and the lockout management parameter = intermittent or temporary intermittent, the state shall be set to intermittent lockout, and intermittent lockout processing is entered (initializing case).

3.4.8.5.4.3 Intermittent lockout cycle parameters.- The nominal cycle for intermittent lockout shall be defined by a pair of parameters: an unlock duration (UD) and a lock duration (LD):

UD = 2 (1-3, 1) scans.
LD = 8 (4-16, 1) scans.

To achieve the durations LD and UD of actual locking and unlocking of the transponder, it is necessary to consider also the time-out period of the lockout state, nominally 18 sec.

T = transponder Mode S lockout time-out, in scans, i.e.

$$T = \frac{18 \text{ sec}}{\text{Sensor scan period, in sec}}$$

(If T is a fraction, the value shall be rounded up to an integer.)

The nominal lockout cycle shall be represented by the following sequence of commands:

Unlock: DL=0 for UD+T scans.
Lock: DL=1 for LD-T scans.

To prevent arbitrarily prolonged lock and unlock periods under non-nominal conditions, the following limiting values shall be used:

Maximum Lock Duration (LDM). $LDM = LD + (2*UD) - 1$ scans.

Maximum Unlock Duration (UDM). $UDM = (UD + LD) * K$ scans,
where K = 1 (1-3, 1).

3.4.8.5.4.4 Intermittent lockout processing.- A target newly assigned to the intermittent control state shall always be initialized by beginning an unlock period: setting DL = 0, unlock count ULC = 1, and all-call count AC = 0.

For other targets in this state, an update shall be performed according to the following rules:

For targets presently in an unlock period (DL = 0), the unlock count ULC shall be incremented by 1. If the count ULC then exceeds the unlock duration maximum UDM, the period shall be ended by initiating a lock period. If the maximum is not exceeded, the all-call flag, AF, shall then be read. If AF = 0, the all-call count AC, shall not be incremented and the processing ends. If AF = 1, AC shall be incremented by 1 and then tested to see if it has reached the nominal unlock duration UD. If AC is less than UD, there shall be no further action and the unlock period shall continue. If AC = UD, the unlock period shall be ended by initiating a lock period. (A lock period shall be initiated by setting DL = 1 and LC = 1).

For targets presently in a lock period (DL = 1), the lock count LC shall be incremented by 1. If the count LC does not exceed the lock duration LD (with allowance for timeout T), no further action shall be taken and the lock period

shall continue. If LC exceeds the maximum lock duration LDM, the period shall be ended by initiating an unlock period. If LC is less than or equal to LDM but exceeds the duration LD, either outcome may occur depending on the result of a proximity test.

The proximity test is a search for any other Mode S targets satisfying the following conditions:

- (a) The target has an azimuth value which is less than that of the target in process by not more than ΔA . (All such targets will have been recently updated by network management). The value for ΔA shall be the effective mainlobe width of the Mode S antenna.
- (b) The target has a range value which is within $\pm \Delta R$ of the target in process. The value for ΔR shall be the distance corresponding to the duration of an a 1-call reply (64 μ sec or 2^{10} Ku).
- (c) The target is in an intermittent lockout state with either 1) $UL = 1$ and $LC > LD - UD - T + 1$, or 2) $UL = 0$ and $ULC < UD$. (This condition defines the time in which simultaneous unlocking could occur.)

If any target is found for which all three of these conditions are satisfied, the lock period is continued. Otherwise, an unlock period is started.

3.4.8.5.5 Other routine network management tasks.

3.4.8.5.5.1 Issuing track data messages.- Track data shall be sent to each of the sensors in the out-list once each scan.

The following steps shall be executed:

- (a) Flag OSE in the out-list shall be checked to see if the entry belongs to the request outstanding list. If it does not, go to (b). If it does, the expiration counter value OEC shall be checked against a threshold value OECT = 5 (2 - 8, 1). If $OEC < OECT$, one shall be added to the counter. If $OEC > OECT$, the entry in the out-list shall be erased.
- (b) A track data message (3.4.8.4) shall be issued to the sensor(s) in the out-list, unless that sensor was added this scan (in which case a data start message was already issued), provided that the target track status is S_4 .

3.4.8.5.5.2 Servicing incoming network control messages.- Each sector (3.4.6.1.1.4) the network control input buffer shall be emptied and action taken as described in 3.4.8.8 and 3.4.8.9.

3.4.8.5.5.3 Not used.

3.4.8.5.5.4 Alert message initiation.- Once each scan, the following operations shall be performed on each entry in the duplicate address alert table (DAAT, 3.4.6.9.4, see also 3.4.8.8.4.7).

- (a) CTR_1 and CTR_2 shall be incremented by one if they are not already at their maximum value.
- (b) CTR_1 and CTR_2 shall be compared to $CTRTH = 3(2-5,1)$.
- (c) If either or both of the two counters equals or exceeds $CTRTH$, a check of the active control flag (ACF) shall be made. If $ACF = 1$, it shall be set to zero. If $ACF = 0$, the entry in the DAAT shall be erased.
- (d) If both counters are less than $CTRTH$, the coverage map shall be accessed for both positions listed in the DAAT entry and a track alert message shall be issued to all sensors listed there. A similar track alert message, specifying the positions of both targets, shall be issued to all connected ATC facilities.

3.4.8.6 Handling of surveillance boundary crossings.- If the routine checks on sensor assignment (3.4.8.5.2) have concluded that the new set of assigned sensors differs from the set found in the previous scan, the tasks described in this section shall be performed. First the "type" of boundary crossing (3.4.8.6.1) shall be determined and action taken accordingly (3.4.8.6.2). A simple permutation of assigned sensors is here not considered as a boundary crossing. For the purposes of this section, only remote sensors which are connected with the local sensor shall be considered.

3.4.8.6.1 Types of boundary crossings.- Let capital letters identify sensors, with A representing the local sensor and B, C, D, any remote sensors. The design of the coverage map allows the following type of transitions that can be detected by local sensor A:

<u>TYPE</u>	<u>TRANSITION</u>
(a) Addition	A → AB, AB → ABC
(b) Deletion of remote sensor	AB → A
(c) Deletion of local sensor	BCA → BC
(d) Combination (deletion of one remote and addition of another)	AB → AD
(e) Combination (deletion of local sensor and addition)	CA → CD

3.4.8.6.2 Action for each type of boundary crossing.

- (a) For transitions where a new sensor was added (a,d,e) and the track status is S_4 , an entry shall be created or an existing entry changed in the out-list for the target ID and the given sensor. A data start message shall be issued. The new set of assigned sensors is written in the target status list of the surveillance file, except in circumstances as discussed in 3.4.8.6.3. For types (d) and (e) the addition of a sensor is done before the deletion is considered. If the track status is S_1 , a data request message shall be issued to the added sensor.
- (b) For transitions (c) and (e), where the local sensor is to be deleted, a check shall be made to determine if the local sensor is providing track data to other sensors (i.e., an active entry in the out-list exists). If not, the total entry for the given Mode S target shall be erased from the surveillance file. If the local sensor is actively providing track data to another sensor, no further action shall be taken on deletions. If the local sensor was receiving track data, a cancel request message shall be issued to all sensors in the in-list. The new set of assigned sensors together with the cell index and the mode to be written in the target status list of the surveillance file are the ones found from the map (3.4.8.5.2).
- (c) For transitions (b) and (d), where a remote sensor is to be deleted, a check shall be made to determine if that remote sensor is actually receiving, on its request, data from the local sensor (RR set). If the request bit RR for that sensor is not set, its ID is erased from all network management lists of the surveillance file. If the remote sensor was receiving unrequested track data, a data stop shall be issued. If the local sensor was receiving track data from this remote sensor, a cancel request message shall be issued to that sensor. If request bit RR was set, that remote sensor was actively receiving track data; it shall then remain assigned (together with the newly found set of assigned sensors).

3.4.8.6.3 Overload conditions .- The new set of assigned sensors, the new mode and the new cell index, found in the routine tasks (3.4.8.5.2), shall not be written over the previous data in the target status list if, for some reason, (overload of output buffers or communications lines), the data start message cannot be output. The boundary transition will then persist, possibly over several scans. Such overload could occur in the case of recovery of an adjacent sensor following its failure as described in 3.4.8.6.4.

3.4.8.6.4 Sensor recovery.- The recovered sensor (referred to as sensor B) shall issue an OK-status message to all connected sensors. The adjacent connected sensor (referred to as sensor A) reinstates its "normal mode" of using the coverage map (3.4.8.3.4.4). It will thereby detect a boundary transition for all targets in cells affected by the change from "special" to

"normal" mode. The number of boundary transitions could possibly be so large that the resulting number of data start messages to sensor B would cause a communications overload condition. The number of messages sensor A issues shall therefore be limited to a number compatible with a "buffer full" condition. For the targets for which a data start was issued, track data messages shall be issued every scan until sensor B has successfully established track and has sent a cancel request. Sensor A will then be able to issue more data starts at the rate sensor B issues cancel requests. Stimulus for a data start on a new target, not yet serviced, will persist due to the fact that the values for cell index, mode and the old set of assigned sensors are not being overwritten. The recovered sensor handles data start messages as described in 3.4.8.8.

3.4.8.6.5 Remote sensor failure.- When the performance monitoring function declares an adjacent sensor failure, tasks including the following shall be performed:

- (a) The coverage map shall be used in the special mode as described in 3.4.8.3.4.4.
- (b) The new ATCRBS/radar range mask shall be determined as described in 3.4.8.3.6.

3.4.8.6.6 Communications failure and recovery.- When the performance monitoring function declares a sensor-to-sensor communications failure or recovery (3.4.10.3.4.2), the connected/unconnected indicators for the sensor affected and the unconnected and connected sensor flags (USF and CSF) shall be appropriately updated.

3.4.8.7 Handling of target track status transitions.

3.4.8.7.1 Purpose.- A target track status transition detected on a routine check (3.4.8.5) shall be a trigger for network activity. This section describes specific action to be taken for each status change. Unless otherwise stated, all actions relating to adjacent sensors refer to connected sensors only.

3.4.8.7.2 Possible track status transitions.- Figure 3.4.8-3 lists the transitions possible and identifies transitions to be considered for action. An artificial status category is introduced corresponding to a nonexisting track in the local surveillance file to simplify the description.

3.4.8.7.3 Action on status transitions.- Checks for status transitions shall be made routinely as was described in 3.4.8.5.3. Transitions out of status categories S_1, S_2, S_3, S_4 require action described in this section.

3.4.8.7.3.1 Transition out of status S_1 .- If the reply type found is external data, the new status shall be set to S_3 , with no further action. If the reply type found is roll-call, the new status shall be set to S_4 (see also 3.4.8.7.3.3). If the reply type found is All-Call, the new status shall be set to S_2 .

AMENDMENT-1

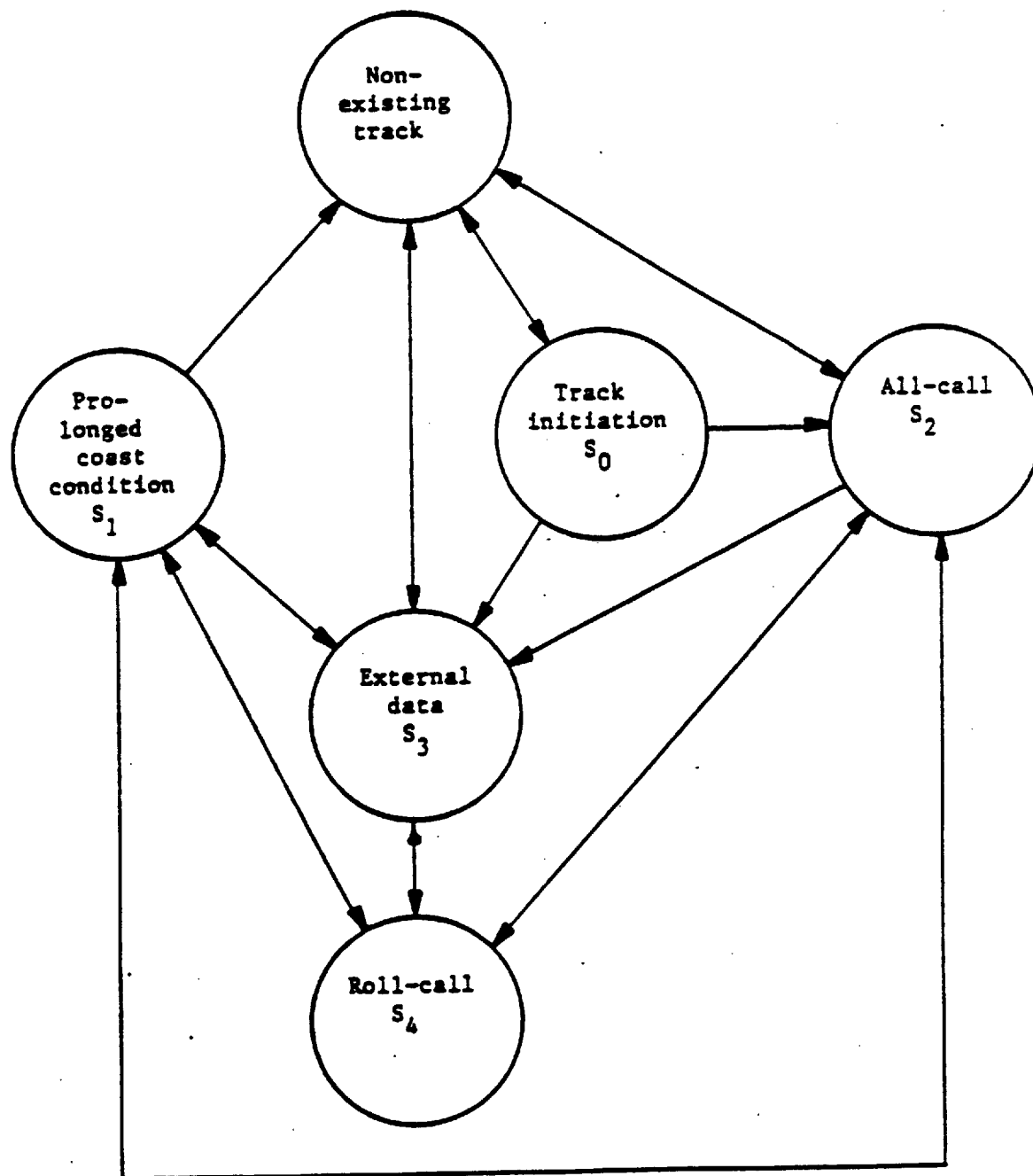


FIGURE 3.4.8-3
STATUS TRANSITION DIAGRAM

3.4.8.7.3.2 Transition out of status S₃. If the reply type found is roll-call, the new status shall be set to S₄ (see also 3.4.8.7.3.3). If no data were received (from any source) the status reverts to S₁. If the request bit TR was not already one, it shall be set to one and a data request shall be issued. If TR is already set to one, a search shall be made of the in-list to find any sensor in addition to the one which has been supplying data (i.e., whose flag IF is set). If there is a sensor listed whose flag IF is not set, its flag shall be set and the others cleared.

3.4.8.7.3.3 Transition into status S₄. Every time a transition into status S₄ occurs, the flag OSE in the out-list shall be checked. If OSE = 1, signifying the entry belonged to the request outstanding list, it shall be reset to 0 and a data start message shall be issued to the sensors listed there. Every time a transition into S₄ occurs (specifically a transition S₁ → S₄, S₃ → S₄) the request bits TR, TRR, and IR shall be checked. Bit TR shall be set to 0. If TRR=0 and IR=0, a cancel request message shall be issued to the sensors listed in the in-list (if any). (See also 3.4.8.9.2). If TRR=1 or IR=1, no action shall be taken.

A transition into S₄ shall always trigger a lockout control state assignment procedure (3.4.8.5.4.2), and a determination of ATCRBS ID code. ATCRBS ID code shall be obtained by setting AI=1 in the surveillance file with the associated sender ID field set to all zeros. The effect of this step shall be to cause the interrogation of the target for the current ATCRBS code value and to disseminate it to all appropriate facilities unless it is identical with the value previously stored (and disseminated).

If the value of basic data link capability (CA) on file is not zero, the capability request flag CAP shall be set in the target status list. (The effect of this step shall be to trigger an interrogation for extended capability data. If the target is new, or if the data have changed they shall be appropriately disseminated). If the file value of CA is zero, the CAP flag shall not be set, but a data link capability message shall be sent to all appropriate facilities, provided that the target is "new". A new target, for this purpose, shall be one for which a data link capability message has never been disseminated. If the target is not new, no further action shall be taken.

Also, a transition into S₄ shall cause the value "no previous broadcast message" to be entered in the broadcast message number field (3.4.1.6.5.3.7.2) of the surveillance file, and shall cause the "new roll-call target" flag to be set.

3.4.8.7.3.4 Transition out of status S₄. If it was found that the track had been coasted for N (3.4.8.2.2) or more consecutive scans, the target track status S shall be set to S₁. If an entry does exist in the out-list, flag OSE shall be set (thus transferring the entry to the request outstanding list) and a data request message issued to all assigned adjacent sensors not in the out-list, if not already done, and bit TR is set equal to one. See also 3.4.8.9.1. If the reply type found is external data while the track is coasting, the new status is S₃. The sensors put in the request outstanding list shall receive a data stop message.

If the reply type found is all-call, the new status is S₂. Sensors in the out-list shall be transferred to the request outstanding list, and shall receive a data stop, but data requests shall not be issued.

3.4.8.7.3.5 Transition out of status S_7 .- If the reply type was found to be equal to roll-call, the status shall be set equal to S_4 and the procedures of 3.4.8.7.3.3 followed.

If the reply type was found to be equal to external, the new status shall be S_3 .

If no reply of any type was found, a coast count is initiated as in 3.4.8.7.3.4 and the status shall be changed to S_1 if the track coasts for N consecutive scans. If S_1 is assigned, TR shall be set to one and a data request issued, as in 3.4.8.7.3.2.

3.4.8.8 Adjacent sensor inputs.

3.4.8.8.1 Purpose.- The purpose is to take appropriate action in response to an incoming network control message from an adjacent sensor. That sensor could issue such a message because of a change in sensor assignment (3.4.8.6) or to coordinate track data exchange in case of a track status change (3.4.8.7) or in response to a message received from the local sensor.

3.4.8.8.2 Inputs.- The inputs shall be any of the set of network control messages discussed in 3.4.8.4 and the information stored in the network management lists described in 3.4.8.2.

3.4.8.8.3 Outputs.- Actions and outputs depend on the specific type of network control message received (see 3.4.8.8.2). Outputs shall be network control messages and updates of the network management lists.

3.4.8.8.4 Action for individual messages.- The first step shall be to recognize the message type code and take action accordingly as now specified. (For type-code assignment see 3.4.8.12)

3.4.8.8.4.1 Data start message.- The following actions shall be taken:

- (a) Check if a track exists in the surveillance file for the given Mode S ID, (i.e., if the target is known to the local sensor).
- (b) If no such track exists, the Mode S address of the data start message shall be checked against the duplicate address alert table (DAAT) (3.4.6.9.4). If the Mode S address is contained in DAAT, then the data start message shall be discarded. Otherwise, the position report which is part of the data start message shall be coordinate converted, time adjusted, and a new entry in the surveillance file shall be created with status $S=S_3$, and CA (basic data link capability) = the value in the data start message (3.4.6.11). Other fields shall be initialized as in 3.4.6.9.3.

- (c) If a track exists, then a reasonableness check (as specified in 3.4.6.8.4.2) shall be performed between the external and the local track positions. If the data start message fails the reasonableness check, then an entry shall be created in the DAAT table (3.4.6.9.4) and the track in the local surveillance file shall be dropped. If the data start message passes the reasonableness check and the local sensor did not request track data (request bits not set) and the track is well established (track status S equal S_4), a cancel request message shall be issued to the sender of the data start message and the report suppressed. Otherwise, the sender ID shall be added to the in-list and further action as in (d) shall be taken.
- (d) A check shall be made in the in-list to see if track data are already being received from another sensor for the same target (IF=1). If so, the IF flag of the sender of the new data start shall be set to 0 and the report suppressed. Otherwise, the IF flag shall be set equal to 1 and action taken as in (e).
- (e) If track status $S \neq S_4$, a coordinate-converted version of the report shall be forwarded to the surveillance processing function. If $S = S_4$, further processing depends on bits IR and TRR. If IR=1, a copy of the report shall be sent to the requesting user. In any case if TRR=1, a coordinate-converted copy of the report shall be stored in a special data buffer referred to as the zenith cone data buffer. In all other cases, the report is suppressed.

3.4.8.8.4.2 Data request message.— The following actions shall be taken:

- (a) Check if an entry in the surveillance file exists for the given Mode S ID.
- (b) If no such entry exists, a data stop message shall be issued to the sender of the data request message.
- (c) If an entry does exist, action shall depend on the track status, S . If $S \neq S_4$, a data stop message shall be issued and an entry created in the request outstanding list with RR = 1. If $S = S_4$, a data start message shall be issued and the ID of the requesting sensor added to the out-list with RR = 1. When a data request is received while track data are already being provided to that sensor, it shall be ignored.

3.4.8.8.4.3 Data stop message.— The sensor ID shall be erased if it was part of the in-list for the given Mode S ID. In the latter case, if the local sensor had requested data and if the IF-flag was one for that sensor and another sensor is listed in the in-list, its IF flag shall be set to one to insure that track data from that sensor, which were already available will be forwarded to the local tracker, other requesting user, or both, as indicated by the setting of the request bits. A data stop message on a target not contained in the surveillance file is ignored.

3.4.8.8.4.4 Cancel request message.- The sensor ID of the sender shall be erased from the out-list, if present, and RR put equal to zero and a data stop issued to that sensor.

3.4.8.8.4.5 Track data message.- A check shall be made to determine if a track with this address exists in the surveillance file. If so, then a reasonableness check (as specified in 3.4.6.8.4.2) shall be performed between the external and local track positions. If the track data message fails the reasonableness check, then an entry shall be created in the DAAT (3.4.6.9.4) and the track in the local surveillance file shall be dropped. If the track data message passes the reasonableness check then the decisions to be made are whether to use the track data and if so where to send them. If the in-list is empty, the ID of the sending sensor shall be placed in the in-list with IF=1. If the in-list has a sensor in it with IF=1 but not that of the sending sensor, the message processing shall be discontinued. If the in-list contains the ID of the sending sensor, examine bit IR. If $S=S_4$ and $IR=1$, the report shall be sent to the requesting user. If track status $S \neq S_4$, the report shall be coordinate converted and forwarded to the track data processing function (3.4.6.11) for updating the track. If $S=S_4$ and $IR=0$, the TRR bit shall be checked. If $TRR=0$, a cancel request shall be issued. If $TRR=1$, the report shall be stored in the zenith cone data buffer. If the address does not exist in the surveillance file, then the DAAT shall be checked. If an entry with this address is not entered in the DAAT, then a track shall be initiated as specified for a data start message (3.4.8.8.4.1). If an entry does exist in the DAAT, then the track data message shall be discarded.

3.4.8.8.4.6 Primary coordination message.- This message shall be used as input to the sensor priority decision procedure (3.4.8.3.5.4 and 3.4.8.3.5.6). This procedure also defines the response message to be sent.

3.4.8.8.4.7 Track alert message.- A check shall be made to determine if the Mode S address of the track alert message is in the DAAT. If it is, then the ACF flag (3.4.6.9.4) shall be set equal to one. Otherwise (a) any existing track with this Mode S address shall be dropped and (b) an entry shall be created in the DAAT with ACF equal to one and CTR_1 and CTR_2 equal to $CTRTH + 1$ (3.4.8.5.5.4).

3.4.8.8.5 Conversion of remote sensor coordinates.- When a data start or track data message is received, the position and velocity in the message are expressed in the coordinates of the remote sensor whose ID is also part of the message. The position is expressed in measured slant range, azimuth and altitude; the velocity in range-rate and azimuth-rate as derived by the surveillance processing function at the remote sensor. The purpose of the coordinate conversion is to express position and velocity in the coordinates of the local sensor.

The following set of equations expresses the coordinate conversion. The parameters a, b, β , and h in the equations are selected based on the ID of the

remote sensor. The values of a and b , expressed as two-way range in R_u , represent the position coordinates of the remote site with respect to the local site, using a Cartesian coordinate system with origin at the local sensor but with axes parallel to the remote site North-South and East-West axes (see fig. 3.4.8-4). The values of h^1 and h are respectively the local and remote sensor elevations above mean sea level expressed in two-way range units (R_u). The value of β expresses the north misalignment between the sensors, with β being positive if the remote site is east of the local sensor and negative if the remote site is west of the local sensor. The magnitude of β is always ≤ 8192 Au (180 degrees). All distances in the equations shall be in two-way range, expressed in R_u , and all angles in Au.

The local coordinates (ρ^1, θ^1, H^1) , and velocity components $(\dot{\rho}^1, \dot{\theta}^1)$ shall then be obtained from the remote position and velocity coordinates $(\rho, \theta, H, \dot{\rho}, \dot{\theta})$, with H the reported aircraft altitude expressed in R_u , using the equations:

$$m = H - h,$$

$$\rho_g = \text{SQRT}(\rho^2 - m^2)$$

$$A = a + \rho_g \sin \theta$$

$$B = b + \rho_g \cos \theta$$

$$\rho_g^1 = \text{SQRT}(A^2 + B^2)$$

$$s = H - h^1$$

$$\rho^1 = \text{SQRT}(A^2 + B^2 + s^2)$$

$$\theta^1 = -\beta + \frac{2^{13}}{\pi} * \text{arctg } A/B$$

$$\text{if } \theta^1 < 0, \theta^1 = \theta^1 + 2^{14}$$

$$H^1 = H$$

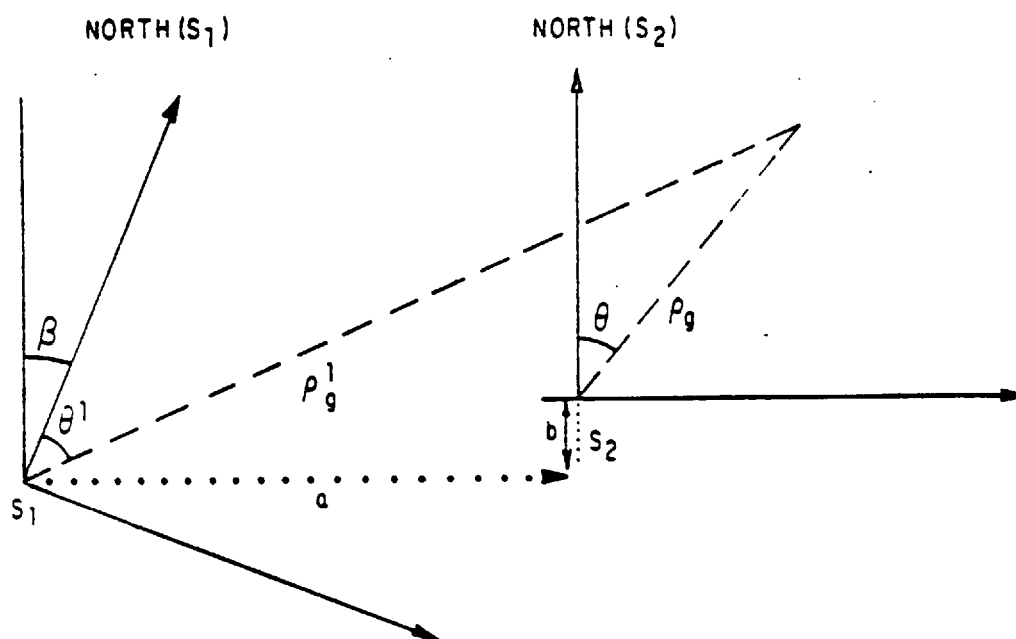
Let

$$\phi = \theta^1 + \beta - \theta$$

$$\text{then } \dot{\rho}^1 = \frac{\dot{\rho}_g}{\rho^1} \left[\frac{\dot{\rho}}{\rho_g} \rho \cos \phi + \rho_g \dot{\theta} \frac{\pi}{2^{13}} \sin \phi \right] K_r \text{ in } R_u/\text{scan}$$

$$\dot{\theta}^1 = \left[\frac{1}{\rho_g^1} (\rho_g \dot{\theta} \cos \phi - \dot{\rho} \frac{\rho}{\rho_g} \frac{2^{13}}{\pi} \sin \phi) \right] K_r \text{ in Au/scan}$$

where $K_r = \frac{\text{local sensor scan period}}{\text{remote sensor scan period}}$



S₁ : LOCAL SENSOR
S₂ : REMOTE SENSOR

FIGURE 3.4.8-4
COORDINATE TRANSFORMATION

The square root and trigonometric functions shall keep approximation errors to less than 1/4 us (4 Ru) in range and 0.088° (4 Au) in azimuth for the position and 1 Ru per second in range rate and 1 Au per second in azimuth rate for the velocity.

3.4.8.9 User inputs.- The action to be taken at reception of a network control message from a user of surveillance netting data is as specified in the following subparagraphs.

3.4.8.9.1 Data request message.- This message, received from the user through message routing management (3.4.8.12), signals to the network management function that external track data are requested. Request bit IR shall be set equal to 1 in the target status list and a data request message issued to the assigned sensors listed in the target status list, if not already done for other reasons. Prior to the coordinate conversion of 3.4.8.8.5 the remote surveillance data shall be sent to the user using the surveillance formats of 3.4.6.14.2.

3.4.8.9.2 Cancel request message.- This message, received from the user through message routing management, shall signal to network management that the user no longer requires external data. The request bit IR shall be reset to zero and a cancel request shall be issued to the sensors listed in the in-list, unless track data are still wanted for other reasons (TR or TRR set).

3.4.8.10 Handling of network control output messages.- Each time a network control message is to be used, the desired message shall conform to the structure specified in 3.4.8.4.

3.4.8.11 Intersensor track data exchange for ATCRBS.

3.4.8.11.1 Purpose.- This function shall handle the exchange between connected sensors of track data on ATCRBS targets having mode C capability. A request for such data exchange shall be triggered either by the entry of the target in the zenith cone of the local sensor, or as a result of the target going into a fade, or as a result of a user request. The mechanism for track data exchange shall be similar to that for Mode S. Its essential components shall be (a) a procedure to detect the need for a data exchange, (b) a set of messages to request, cancel, start and stop the track data flow, and (c) some bookkeeping procedures.

The coverage map shall be accessed for ATCRBS targets only when the need arises to determine where to send the request for data.

3.4.8.11.2 Detection of the need for data exchange.

3.4.8.11.2.1 Fade condition.- A field in the surveillance file called track status S (2 bits) shall be routinely updated and checked. Status value $S=S_2$ shall indicate normal tracking conditions, $S=S_3$ that the track is maintained on external data, $S=S_1$ that the track is in an extended coast condition defined as the fact that track firmness $f \geq FEC = 3(2-5, 1)$. A transition $S_2 \rightarrow S_1$ shall cause an ATCRBS data request message to be issued to the best remote assigned sensor, as can be determined from the coverage map. A transition $S_3 \rightarrow S_2$ shall trigger an ATCRBS cancel request, unless the TRR or IR bits are set (see 3.4.8.11.2.2 and 3 and 3.4.8.11.4.2.1). Network management shall remember that it issued or cancelled a data request by the setting of the TR bit in the track record.

3.4.8.11.2.2 Zenith cone condition.- The zenith cone condition sets up a track data exchange in anticipation of a target fade. As part of the track status update, a check shall be made to determine if the target is within a range of $ZCTHR = 2^{10}$ ($2^{10}-2^{11}$, 2^{10}) Ru and at an elevation greater than BE (as defined in 3.4.8.5.2, subparagraph (1)), these two conditions defining the extent of the zenith cone. If the target is in this cone, ATCRBS data must be requested from the best remote assigned sensor, as determined from the coverage map. Network management shall remember its request by the setting of the TRR request bit in the track record. When the bit is first set equal to one or when it is reset from one to zero, this resetting shall trigger an ATCRBS data request or an ATCRBS cancel request, respectively, unless superseded by a fade condition or a user request for data.

If the target range is within ZCTHR and at an elevation greater than RE (3.4.8.5.2, (1)), the radar zenith cone flag RZC shall be set to one. Otherwise, it shall be set to zero.

3.4.8.11.2.3 User request for ATCRBS data.- When a user of surveillance netting data addresses an ATCRBS data request/cancel message to the sensor, network management shall remember this request by the setting of the IR bit in the target status list of the track record. It will issue an ATCRBS data request to the best remote assigned sensor(s) or issue an ATCRBS cancel request, unless the fade-bits TR or zenith cone bit TRR are set. Prior to the coordinate conversion of 3.4.8.8.5 the remote surveillance data shall be sent to the user using the surveillance formats of 3.4.6.14.2.

3.4.8.11.3 Network management messages for ATCRBS data exchange.

3.4.8.11.3.1 Functional significance.- An ATCRBS data request message shall request data from the addressed sensor on the target identified in the message. If the receiving sensor can unambiguously identify the target in its local surveillance file (as specified in 3.4.8.11.4.2.1), it shall answer with an ATCRBS data start message. The receiving sensor shall continue to provide

data each scan until such time as an ATRBS cancel request message is received or the sensor is no longer able to provide data. In either case, the receiving sensor shall issue an ATRBS data stop message. If the sensor is unable to uniquely identify the target in its local surveillance file, it shall answer with an ATRBS data stop message to indicate it is unable to comply with the request.

3.4.8.11.3.2 ATRBS data exchange message formats. The formats shall be as summarized herein: The formats are read as follows. Message bit numbers represent required field length, and are placed under the message formats. Field bit lengths are in () if required length. Field bit lengths are in () if minimum length. Bit numbers, except 1, are left off any messages with the bit length specified this way. Spare (zero) bits and data bits added to fields, may be used for field alignment as long as the average overhead, due to these bits, is not greater than 20 percent.

The typecode assignments for these messages are found in 3.4.8.12.2 and 3.4.8.12.6.3.

ATRBS Data Request Message

type code	requesting sensor	ATRBS	range	az	altitude	RSID	SSID
(8)	track number (12)	code (12)	(16)	(14)	(10)	(10)	(10)

1

ATRBS Track Data Message

type code	requesting sensor	ATRBS	code con-	meas.	meas.
(8)	track number (12)	code (12)	fidence (12)	range (16)	az. (14)

1

range	az.	altitude	alt. con-	time reference	RSID	SSID
rate (8)	rate (8)	(12)	fidence (12)	(8)	(10)	(10)

ATRBS data start message

The format shall be identical to the ATRBS track data message, but the type code shall differ.

ATRBS data stop message

type code	requesting sensor	ATRBS code	RSID	SSID
	track number			
1	8 9	20	32 33	42 43 52

ATRBS cancel request message

The format shall be identical to the ATRBS data stop message but the type code shall differ.

3.4.8.11.4 Network management tasks related to ATCRBS data exchange. - Part of the tasks shall be routine tasks, performed once a scan for each ATCRBS target with mode C. The routine task shall consist of checks to detect the need for data exchange (fades, zenith cone, see 3.4.8.11.2) and issuance of the appropriate ATCRBS data request/cancel request message when conditions require. A second routine task shall be the forwarding of an ATCRBS track data message for ATCRBS targets on which the local sensor is providing data to a remote sensor. Nonroutine tasks shall consist of reacting to messages incoming from a remote sensor or from another user. These reactions consist of replying with the appropriate message and updating bookkeeping files.

3.4.8.11.4.1 ATCRBS network management lists. - For bookkeeping purposes the network management function shall add fields to the track record of ATCRBS targets with mode C capability. In analogy with Mode S these fields are grouped in lists and labeled (Table 3.4.8-5).

TABLE 3.4.8-5

ATCRBS NETWORK MANAGEMENT LISTS

<u>List Name</u>	<u>Field Definition</u>	<u>Symbol</u>	<u>No. of bits</u>
Target Status List	Target Track Status	S	2
	Request bit for fade	TR	1
	Request bit for zenith code	TRR	1
	Request bit for other user	IR	1
In-list	*First sensor ID	.	4
	*Flag for active use	IF	1
Out-list	*First sensor ID	.	4
	*First sensor remote track number	.	12

*Repeated for additional sensors as needed.

Bits TR, TRR, IR allow the local sensor to store the reason for which it requested external data. When the local sensor receives track data from a remote sensor, it shall store the ID of the sender in the in-list. When the local sensor is able to comply to a data request from a remote sensor, the ID of that destination shall be stored in the out-list, and used to issue track data every following scan. Also in the out-list is the track number for the target with respect to the requesting sensor. The track data message shall repeat this number to allow easy association of the data to the track at the receiving sensor. Flag IF shall indicate whether the track data are actively used by the local sensor.

3.4.8.11.4.2 Handling of ATCRBS data exchange messages. - This section describes the action taken at receipt of any of the ATCRBS messages listed in 3.4.8.11.3.

3.4.8.11.4.2.1 Action for the ATCRBS data request message. - The receiving sensor shall search through its local surveillance file to identify the corresponding track based on a simple association check. If no such track or several such tracks are found, an ATCRBS data stop message shall be issued. If one and only one track was found, the sender ID and the track number shall be written in the out-list and an ATCRBS data start shall be issued. The association check for unique ATCRBS with 4096 code consists of matching that code against the local list of ATCRBS codes in an attempt to uniquely identify a local track. If several tracks with matching code are found, the unique track which lies within $ADIS = 2^9 (2^8 - 2^{10}, 2^8)$ Ru of the ρ, θ position specified in the ATCRBS data request message (after coordinate conversion, 3.4.8.8.5) shall be selected. For nonunique ATCRBS, the association is based first on position and then on code as follows: a sector is identified based on the 5 most significant bits of the coordinate converted azimuth. That sector, plus one preceding and one following, are searched and the single track with matching code and within distance ADIS of the position in the data request shall be selected. As before, if none or several tracks are found, no association shall be made.

3.4.8.11.4.2.2 Action for the ATCRBS data start message. - The receiving sensor shall check if TR or TRR or IR equals one. If not, it shall issue an ATCRBS cancel request message. Otherwise, the sender ID shall be written in the in-list of the track record whose number is given in the message. A check shall be made in the in-list to see if track data are already being received from another sensor for the same target (IF=1). If so, the IF flag of the sender of the new data start shall be set to 0 and the report suppressed. Otherwise, the IF flag shall be set equal to 1 and action taken as in 3.4.8.11.4.2.3.

3.4.8.11.4.2.3 Action for the ATCRBS track data message. - If IF=0, the message is ignored. If IF=1, it is further considered. If request bit TR=1 or if TRR=1 and track status $S \neq S_2$, the report is coordinate-transformed (3.4.8.8.5) and forwarded to the ATCRBS track data processing function. If IR=1, the report is forwarded to the requesting user. If $S=S_2$ but TRR=1, the report shall be coordinate-converted and stored in the zenith cone data buffer.

3.4.8.11.4.2.4 Action for ATCRBS data stop message. - If the local sensor is still requesting data (TR=1 or TRR=1 or IR=1) and if the sensor sending the data stop message has its IF flag=1, then the in-list shall be checked for the presence of the ID of a second sensor with its IF flag set to 0. If found, the IF flag of the second sensor is set to 1. The ID and IF flag of the sender of the data stop is erased from the in-list (if present).

3.4.8.11.4.2.5 Action for ATCRBS cancel request message. - The action consists of emptying the sender ID field in the out-list of the track record.

3.4.8.11 4.2.6 Action for ATCRBS data request/cancel from another user. - The sensor shall set or reset the IR-bit in the target status list and issue an ATCRBS data request or ATCRBS cancel request message to the appropriate sensor, unless overwritten by a fade or zenith cone condition (i.e., a request had already been issued or no cancel should be issued because data are still wanted for other reasons).

3.4.8.12 Message routing management.

3.4.8.12.1 Purpose. - The purpose is to route incoming messages to the appropriate subsystem (network management, sensor performance monitoring or data-link processing). On one class of messages, acceptance tests shall be performed. Additionally, message routing management shall direct the dissemination of air-initiated messages and perform certain tasks in support of non-ATC users of the data link. The block diagram shown in fig. 3.4.8-5 specifies the general flow of messages handled by the message routing management function.

3.4.8.12.2 Inputs. - The inputs processed by the rules of 3.4.8.12.5 shall include the following messages:

<u>Type Code</u>	<u>Name</u>
------------------	-------------

(a) ATC-to-Sensor Uplink Messages

0010 0001	Tactical Uplink Message (to a Mode S aircraft)
0010 0010	ELM Uplink Message (to a Mode S aircraft)
0010 0011	Request for Downlink Data (from a Mode S aircraft)
0010 0100	ATCRBS ID Request (to a Mode S aircraft)
0010 0101	Uplink Message Cancellation Request (of a previous message)

(b) ATC-to-Sensor Status/Control Messages

0110 0001	Test Message (to a Mode S sensor)
0110 0101	Sensor Failure/Recovery Message
1001 1001	ATC Failure/Recovery Message
1001 1010	Mode S Aircraft Control State Message

(c) Sensor-to-Sensor Network Control Messages

1001 0001	Data Start
1001 0010	Data Stop
1001 0011	Data Request
1001 0100	Track Data
1001 0101	Cancel Request
1001 1101	Primary Coordination Message
1001 1110	Track Alert Message

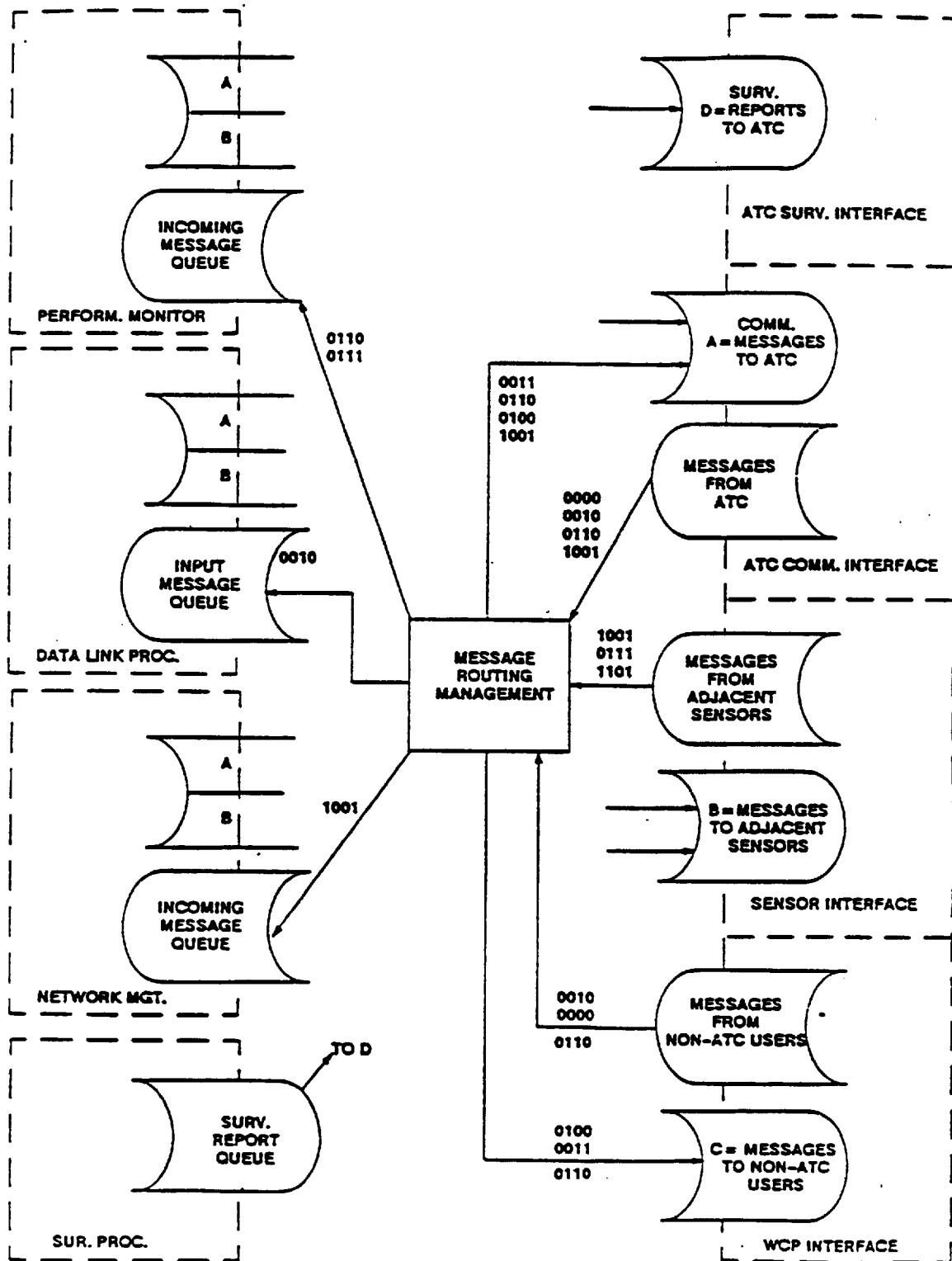


FIGURE 3.4.8-5. CONTEXT OF MESSAGE ROUTING FUNCTION

(d) Sensor-to-Sensor Status Messages

0111	0001	Sensor Status Message (routine)
0111	0010	Sensor Status Request (about third sensor)
0111	0011	Sensor Status Response (about third sensor)

(e) Sensor-to-Sensor ATCRBS Data Exchange Messages

1101	0001	ATCRBS Data Start
1101	0010	ATCRBS Data Stop
1101	0011	ATCRBS Data Request
1101	0100	ATCRBS Track Data
1101	0101	ATCRBS Cancel Request

(f) ATC-to-Message Routing Management

0000	0010	Data Link Capability Request
------	------	------------------------------

(g) NON-ATC-to-Sensor Uplink Messages (from non-ATC User)

0010	1001	Tactical Uplink
0010	1010	ELM Uplink
0010	1011	Request for Downlink Data
0010	1101	Message Cancellation Request
0010	0100	ATCRBS ID Request

(h) NON-ATC-to-Message Routing Management (from non-ATC User)

0000	1010	Data Link Capability Request
0000	1000	Request for Aircraft State
0000	1001	Request for Aircraft Position
0110	0001	Test message (to a Mode S sensor)

Note: The Uplink messages and the Data Link Capability Request received via the NON-ATC user have the same data contents as the corresponding ATC-to-Sensor messages. Data contents for the remaining NON-ATC messages are given in 3.4.8.12.5.3.

Other inputs are the outgoing messages generated by various sensor software functions. They are discussed further in 3.4.8.12.6.

3.4.8.12.3 Outputs.- Except for those messages addressed to the message routing management itself (3.4.8.12.5.3), the outputs from the processing described in 3.4.8.12.5 shall include the same incoming messages, appropriately routed within the sensor. Additional outputs include a message rejection/delay notice that can be issued to the sender (3.4.8.12.5.2), a test response message, and several other messages for non-ATC users only (3.4.8.12.5.3). All outputs from the processing described in 3.4.8.12.6 are described in 3.4.8.12.6.3.

3.4.8.12.4 Message type code.- The message type code specified in 3.4.8.12.2 allows the message routing management function to recognize the destination by reading the type code.

3.4.8.12.5 Rules of operation.- The type code shall be read and action taken accordingly. Figure 3.4.8-5, shows which messages (prefix of type code is indicated on the arrows) are sent to each subsystem by message routing management.

3.4.12.5.1 General message routing function.- For all messages not specifically discussed in 3.4.8.12.5.2 or 3.4.8.12.5.3, the message shall simply be transferred to the appropriate buffer, based upon the type code.

3.4.8.12.5.2 Messages to data link processing.- For messages to the data link processing function (prefix 0010), acceptance testing shall be performed as follows:

- (a) If no track entry exists in the surveillance file for the Mode S target addressed, the uplink message (of any kind) shall be dropped and a message rejection/delay notice issued to the sender (ATC facility or other data link user). The content of the message (Qualifier field) shall indicate the reason for the rejection: "target not on file".
- (b) If the message is of the type ELM uplink and the data link capability field (CA) on file indicates that the target does not have ELM capability, the message shall be rejected with the rejection notice qualifier indicating the reason, "target lacks ELM capability". Uplink ELM capability is indicated by the presence of a code value of 010 or 011 in the CA field, as defined in the Mode S National Standard.
- (c) If the message is of the type ELM uplink and the sensor priority status PS has the value S for the aircraft addressed, the message shall be rejected with the rejection notice indicating the reason: "sensor not primary".

If, in this case, the rejected ELM uplink had been sent by a non-ATC user, the rejection notice shall be of the type "Message Rejection Notice with sensor IDs" (type code 0011 1001). This notice format has two fields in addition to those of the rejection notice to an ATC

facility. These are sensor ID fields (SID1 and SID2, each 10 bits on external ground links, and 4 bits otherwise, see 3.4.8.2.2(e)). Values shall be assigned by reference to the Target Status List of the aircraft addressed. The ID code of the highest-priority adjacent assigned sensor, if any, shall be entered in SID1, and that of the second-highest-priority adjacent assigned sensor, if any, in SID2. If there are fewer than two adjacent sensors assigned, the corresponding SID fields shall contain all zeroes. The notice shall be addressed to the sender of the ELM uplink.

- (d) No further action is taken for a message which is rejected in any of the preceding tests. Otherwise, the message is accepted and placed in the input message queue for further handling.
- (e) For each accepted message, the track state S of the target addressed is examined. If the $S=S_4$, there is no further action. Otherwise, a rejection/delay notice is issued with the qualifier indicating the reason: "target not in roll-call mode".

For all messages put in the input queue, the message routing management function shall append to the message the storage location of the Mode S target entry in the surveillance file.

When an uplink message cancellation request is received, action shall differ slightly according to type code. However, in all cases, a search shall be made through the input message queue of the data link processing function to identify the message to be canceled (by matching Mode S ID, message number). If it is found, it shall simply be erased. If it is not found, the uplink message cancellation request is added to the input message queue for further consideration by data-link processing.

3.4.8.12.5.3 Other message routing tasks.

The receipt of a data link capability request message from either an ATC or a non-ATC user shall result in the retrieval of the capability field (including basic and extended capability data as applicable) from the surveillance file for the referenced Mode S address. A data link capability message shall be formatted and sent to the requesting facility. If the Mode S address is not on file, a message rejection/delay notice shall be issued to the sender, as in 3.4.8.12.5.2(a).

A message of the type "test" (prefix 0110) shall not be routed to the performance monitoring function. Instead, it shall result in the generation of an output message of the type "test response", whose format is defined in FAA-RD-80-14. The test response data in this message shall be a duplicate of the test data in the received message. The test response message shall be addressed to the sender of the test message and placed in the appropriate output buffer.

Whenever a Mode S track drop notification is received from the surveillance

processing function (3.4.6.10.4.1), a Track Drop Message shall be generated. This message (type code 0100 1011) contains the following data fields:

Mode S Address
SID1
SID2

SID1 and SID2 shall be assigned as in 3.4.8.12.5.2 (SID1 and SID2, each 10 bits on external ground links, and 4 bits otherwise, see 3.4.8.2.2(e)). The message shall be addressed to the non-ATC user.

Receipt of a Request for Aircraft State message shall result in the generation of an Aircraft State message addressed to the sender. The Request (type code 0000 1000) contains one data field: the Mode S Address. The response message (type code 0100 1110) contains the same Mode S Address and an additional field, A/C State. The value of A/C State shall be determined by reference to the Target Status List of the aircraft addressed, and shall express one of the following conditions:

A/C not on file
A/C on file, but not in track state S_4 (full track)
A/C in track state S_4 , controlled primary
A/C in track state S_4 , controlled secondary
A/C in track state S_4 , uncontrolled primary
A/C in track state S_4 , uncontrolled secondary

Receipt of a Request for Aircraft Position message shall result in the generation of an Aircraft Position message addressed to the sender. The Request (type code 0000 1001) contains one data field: the Mode S Address. The response message (type code 0100 1111) contains the same Mode S Address and the following additional fields, to be assigned by reference to the Target Status List and the Surveillance File of the aircraft addressed:

- (1) A/C State, as defined for the Aircraft State message;
- (2) A/C Range, one-way measured range in nautical miles, truncated to 10 bits (MSB = 128, LSB = 0.25);
- (3) A/C Azimuth, measured azimuth in degrees, truncated to 12 bits (MSB = 180, LSB = 0.088);
- (4) A/C Range Rate, predicted one-way range rate in nautical miles/sec, truncated to 6 bits including sign (MSB = 0.2, LSB = 0.0125);
- (5) A/C Azimuth Rate, predicted azimuth rate in degrees/sec, truncated to 8 bits including sign (MSB = 2, LSB = 0.031);
- (6) Altitude, 12-bit Mode C altitude in hundreds of feet (as reported in Surveillance Message).

Receipt of an ATC Failure/Recovery Message announcing failure shall result in the setting of an appropriate flag, for the use of other sensor functions. This flag shall be reset upon receipt of a message announcing recovery.

3.4.8.12.6 Sensor output message handling.- As indicated in fig. 3.4.8-5, output messages generated by the various sensor functions may be placed directly in a buffer accessible to another internal function, or in an output buffer if they are addressed to a specific external facility, without further intervention by message routing management except as noted in 3.4.8.12.6.2.

Messages with a general (all zeroes) external address shall be processed further to determine the appropriate dissemination. These messages include the following types (when not generated in response to a specific user request): Status, Sensor Recovery, Pilot downlink, Ground-initiated downlink, Broadcast downlink, ELM downlink, ATCRBS ID notice, Data link capability, Track alert, and Track drop. Each of these messages shall be processed to determine dissemination first to ATC facilities (3.4.8.12.6.1) and then to non-ATC users (3.4.8.12.6.2).

3.4.8.12.6.1 Dissemination to ATC facilities.- Messages of the types Status, Sensor Recovery and Track alert shall be addressed for dissemination to every connected ATC facility. Messages of the type Track drop shall not be sent to any ATC facility.

Messages of the types ATCRBS ID, Data link capability, Ground-initiated downlink, Pilot downlink, Broadcast downlink, and ELM downlink shall be disseminated according to the position (range, azimuth, and altitude) of the referenced aircraft, using the same rules and procedures which apply to the dissemination of surveillance data (3.4.6.14.3).

3.4.8.12.6.2 Dissemination to non-ATC users.- Messages of the types Data link capability, Sensor Recovery, ATCRBS ID, Track alert, and Track drop shall be sent to the non-ATC user address (to be provided as part of site adaptation). Messages of the type Status, shall not be sent to the non-ATC user.

Messages of the types Pilot downlink, Broadcast downlink, Ground-initiated downlink, and ELM downlink shall be disseminated without regard to aircraft position. According to the value of a site-adapted parameter defined for this purpose, such messages shall be sent in either of two forms: unmodified or with position data appended.

If position data are to be appended, the message shall be modified by changing its type to Pilot Downlink with Position (type code 0100 1001) Ground-initiated Downlink with Position (type code 0100 1100), Broadcast Downlink with Position (type code 0100 1000), or ELM Downlink with Position (type code 0100 1010), and appending six additional data fields. These fields are A/C State, A/C Range, A/C Azimuth, A/C Range Rate, A/C Azimuth Rate, and Altitude, and they shall be set as specified for the Aircraft Position message (3.4.8.12.5.3).

Ground-initiated downlink messages containing a specific (non-zero) sender ID which identifies a non-ATC facility shall be sent to that facility only. However, such messages shall have aircraft position data appended, or not, according to the procedure defined above for messages with general (all-zeroes) sender ID.

3.4.8.12.6.3 Output message listing.- The following list gives all the sensor output message types with their type codes. Whenever appropriate the list identifies the output buffers (as shown in fig 3.4.8-5) into which the message may be placed, either by the originating function or by message routing management:

- (a) Output messages from the performance monitoring function (3.4.10.3.2).

Type Code	Name
0111 0001	Status message to adjacent sensor (buffer B)
0111 0010	Status message request (about third sensor) (buffer B)
0111 0011	Status message response (about third sensor) (buffer B)
0110 0100	Status message to ATC (buffer A)
0110 1111	Sensor recovery notice message (buffer A, C)

- (b) Output messages from data-link processing (3.4.7.3.3).

0100 0010	ELM downlink (buffers A, C)
0100 0101	ATCRBS ID notice (buffers A, C)
0100 0001	Pilot downlink (buffers A, C)
0011 0010	Uplink message delivery notice (buffers A, C)
0011 0001	Message rejection/delay notice (buffers A, C)
0011 1001	Message rejection notice with sensor ID (buffer C)
0011 0100	Data link capability message (buffers A, C)
0100 0000	Broadcast downlink (buffers A, C)
0100 0100	Ground-initiated downlink

- (c) Output messages from message routing management.

0011 0001	Message rejection/delay notice (buffers A, C)
0011 1001	Message rejection notice with sensor ID (buffer C)
0011 0100	Data link capability (buffers A, C)
0110 0010	Test response (buffer A)
0100 1011	Track drop message (buffer C)
0100 1110	Aircraft state message (buffer C)
0100 1111	Aircraft position message (buffer C)
0100 1001	Pilot downlink with position (buffer C)
0100 1010	ELM downlink with position (buffer C)
0100 1000	Broadcast downlink with position (buffer C)
0100 1100	Ground-initiated downlink with position (buffer C)

(d) Output messages from network management (3.4.8.4 and 3.4.8.11.3).

1001	0001	Data Start (buffer B)
1001	0010	Data Stop (buffer B)
1001	0011	Data Request (buffer B)
1001	0100	Track Data (buffer B for adjacent sensor; buffer A for requesting user of netted data)
1001	0101	Cancel Request (buffer B)
1001	1101	Primary Coordination Message (buffer B)
1001	1100	Track Alert Message (buffer A, C)
1001	1110	Track Alert Message (buffer B, for sensor to sensor)
1101	0001	ATCRBS Data Start (buffer B)
1101	0010	ATCRBS Data Stop (buffer B)
1101	0011	ATCRBS Data Request (buffer B)
1101	0100	ATCRBS Track Data (buffer B)
1101	0101	ATCRBS Cancel Request (buffer B)

(e) Output messages from surveillance processing.

Surveillance reports for Mode S, ATCRBS and radar targets (buffer D)

3.4.8.12.6.4 Message numbering.- Output messages for ATC and non-ATC, shall contain 8-bit message number fields as defined in FAA-RD-80-14. These fields shall be set as follows:

- (a) For messages which are responses to uplink messages (rejection and delivery notices), the field contains a referenced message number. The field shall be set equal to the value in the message number field in the corresponding uplink message. The message number field shall also be set in this manner for the following types of message: tactical downlink and tactical downlink with position (when generated in response to a request for downlink data), test response, aircraft state, aircraft position, ATCRBS ID Code (when response to an ATCRBS ID request), and data link capability (when generated in response to a capability request).
- (b) For other messages referring to a Mode S aircraft (except track alert), the message number shall be set to 128. This supersedes the message numbering, as specified in FAA-RD-80-14, for messages from the sensor.
- (c) For all other messages containing a message number field (i.e., track alert and messages without a Mode S address field), the message number shall be set to 128.

FAA-E-2716

-341-

3.4.9 (Not used.)

This space not used intentionally.

This page not used intentionally.

3.4.10 Performance monitoring.

3.4.10.1 Description.- This function monitors sensor operation through checks performed using:

- (a) The Calibration and Performance Monitoring Equipment (CPME).
(see Appendix VIII).
- (b) Adjacent sensor data (transmitted and received via sensor/ATC communication ports).
- (c) Sensor hardware.
- (d) Sensor software.

Performance monitoring tests shall be performed in such a manner that an indication of the failed lowest replaceable unit (LRU) shall be contained in the sensor status message (see FAA-RD-80-14). In addition to the parameters specified in the following subparagraphs, sufficient information shall be made available to the performance monitoring function to enable it to identify a faulty LRU for 90% of all possible failures.

When redundant elements are employed to achieve the required reliability, back-up elements shall be tested to the same extent as the operational elements without degradation or disruption of sensor operation. The failure of a back-up element shall be reported in the sensor status message.

Monitors required for sensor hardware measurements are specified in 3.4.10.2. Section 3.4.10.3 specifies the software function required to implement the performance monitoring function. A performance monitor display and a maintenance I/O device are required for each sensor as specified in 3.4.10.4 and 3.4.10.5. Requirements for interoperation with the FAA remote maintenance monitoring system (RMMS) are specified in 3.4.10.6.

Performance monitoring shall provide all of the sensor status information needed by the RMMS to support the maintenance concept contained in Appendix X.

3.4.10.2 Hardware monitors.- The purpose of these monitoring functions is to provide an indication of sensor hardware status beyond the full loop check performed via the CPME's. The items monitored shall include but not be limited to: (a) transmitter peak forward and reflected power, (b) receiver RF to video transfer characteristics and noise levels, (c) monopulse off-boresight indication signals for simulated test target inputs, and (d) ATCRBS and Mode S processor outputs. System clock status (3.4.13) and azimuth register status (3.4.4.7.1) are received for entry in the status buffer. The status of the communications subsystem and the sensor status and alarm panel shall also be monitored.

3.4.10.2.1 On-line transmitter/receiver monitor.- Figure 3.4.10-1 is a block diagram of the on-line monitor. The data acquisition portion shall consist of an analog multiplexer that connects one of the several test points to a sample-and-hold circuit and an A/D converter. The digitized data for a complete monitor cycle shall be processed and transferred to the sensor computer under control of the performance monitor function.



For receiver monitoring, an RF pulse generator shall be coupled into the three antenna lines: sum, difference and omni. On a noninterfering basis, a single test pulse of amplitude, approximately -50dBm, shall be distributed to three injection points. In addition, Mode A and Mode S replies derived from the test target generator (3.4.14) shall be injected to test the standby channel receiver functions. A switch shall be provided to terminate the coupler input to the difference channel for the duration of a test pulse. The interconnection of the on-line monitor with the RF receiving system is shown in Fig. 3.4.2-3.

3.4.10.2.2 Monitor interface. The monitor shall interface with the operational sensor equipment at the following points:

(a) Inputs:

- Main transmitter forward and reflected peak power
- SLS transmitter forward and reflected peak power
- Sum video
- Auxiliary sum video
- Omni antenna video
- Off-boresight video
- Control from modulation control consisting of interrogation type (Mode S or ATCRBS), and Mode S power program (normal or high)
- Synchronization pulse at transmit time from modulator control
- Real-time clock status (3.4.13.4)
- Azimuth register status (3.4.4.7.1)
- Test target generator status (3.4.14)
- Communications subsystem status (3.4.10.2.4)
- Status and alarm panel (3.4.10.2.5)
- Computer status (3.4.10.3.5.7 and 3.7.2.4(f))
- RMMS interface (3.4.10.6)
- CW interference azimuth(s) (3.4.3.2.5.1)

(b) Outputs:

- Sum test signal to RF coupler in sum antenna line
- Omni test signal to RF coupler in omni antenna line
- Difference test signal to RF coupler in difference antenna line
- Sensor hardware status message
- RMMS
- Data extraction
- TTG

The RF signal paths to the sum and difference couplers shall be zero-phase balanced to $\pm 4^\circ$. The test signals (from the RF Pulse Generator) shall simulate two target azimuths: (a) on boresight ($\Delta = 0$) and (b) off-boresight at the sum and difference crossover points ($\Delta = \Sigma$).

The forward and reflected sum and omnidirectional transmit power monitoring shall have sufficient resolution to detect a 0.1 change in VSWR at the sensor RF port, and accuracy to measure VSWR to ± 0.2 with a 95% confidence level, over a 10dB variation in transmit power and over a VSWR range of 1.1:1 to 1.8:1.

3.4.10.2.3 Monitor synchronization.- Timing for monitor operation shall be derived from a transmission time pulse (TTP) issued by modulation control. Over a sequence of transmissions, the monitor shall automatically cycle through the required measurements at each test point. The corresponding buffer shall be updated by the most recent measurement of its type. A cycle of measurements shall be initiated each time the buffer is read by the sensor computer.

For transmitter forward and reflected power monitoring, the sampling strobes are delayed from TTP so as to sample P_1 on the main transmitter and P_2 and P_3 on the SLS transmitter. For receiver monitoring, a pulse shall be injected so as to fall into an interval free of transmitter leakage, e.g., 5 μ s after the P_1 of an ATCRBS interrogation. The video outputs of the standby channel shall also be sampled for noise level in the absence of injected signals. At least 32 noise samples per scan shall be used to compute the average. At least 128 (32-256, 32) samples of the boresight and crossover ($\Delta - \Sigma$) monopulse video shall be used to compute the average each scan.

3.4.10.2.4 Communication subsystem monitor.- The items to be monitored for the communications subsystem shall include but not be limited to:

- Receipt of an unrecognizable message type
- Communications buffer overflow condition - Communications
- Communications buffer overflow condition - Surveillance
- Modem failure - Communications
- Modem failure - Surveillance
- Loss of intersensor communications and site number.
- Identity of failed communication line.
- Communication (TELCO) line error detection (e.g. availability, data transfer error rates, error types).

3.4.10.2.5 Status and alarm panel.- Abnormal temperature conditions detected by the status and alarm panel (3.11.2.5) shall be reported to the performance monitoring function.

3.4.10.2.6 Data format.- One entry in the buffer shall be allocated for each item. The resolution shall be sufficient to observe a 10 percent deviation from the lowest nominal level at each test point, and so that a 0.1 change in VSWR at the sensor RF port can be detected from the measured transmitter forward and reflected powers. The data items shall include but not be limited to:

- Main forward and reflected transmitter powers for ATCRBS
- SLS forward and reflected transmitter powers for ATCRBS
- Main forward and reflected transmitter powers for normal Mode S
- SLS forward and reflected transmitter powers for normal Mode S
- Main forward and reflected transmitter powers for high-power Mode S
- SLS forward and reflected transmitter powers for high-power Mode S

Sum channel video signal
Auxiliary sum channel video signal
Sum channel video noise (valid only for standby channel)
Delta channel video signal
Delta channel video noise (valid only for standby channel)
Omni channel video signal
Omni channel video noise (valid only for standby channel)
Off-boresight indication signal for $\Delta = 0$
Off-boresight indication signal for $\Delta = \Sigma$
System clock status
Azimuth register status
Status and alarm panel status
Communications status
Test target generator test status
CW interference azimuth(s)

The design shall ensure that data will be used only once and that residual data cannot be interpreted as new values. All zeros shall not be valid data value.

3.4.10.3 Performance monitor software. - The purpose of the performance monitor software is to continuously check the operation of the sensor and generate appropriate status messages depending upon the results of this check. The inputs, outputs, and tests performed are specified in 3.4.10.3.1 to 3.4.10.3.6. The decision algorithm that uses test results to declare sensor status is specified in 3.4.10.3.7.

Parameter values specified herein for the frequency of occurrence of each of the checks and the decision points for declaring marginal operation, or failure, are nominal values. The performance monitoring function shall be implemented in such a way that these values may be easily modified.

3.4.10.3.1 Inputs. - Inputs to the performance monitor function shall include, but not be limited to, the following:

(a) CPME originated inputs:

Mode S All-Call reports
Mode S target reports
ATCRBS target reports
Mode S downlink messages

(b) Sensor hardware inputs:

Main transmitter forward and reflected power outputs for ATCRBS,
Mode S low power and Mode S high power.
Omni transmitter forward and reflected power outputs for ATCRBS,
Mode S low power and Mode S high power.

Receiver output to a known input test pulse for each receiver video channel, and to a known input reply for the S channel.
Receiver noise output for each video channel (valid only for standby channel).
Monopulse outputs for test inputs simulating targets on- and off-boresight.
System clock status.
Azimuth register status
Test target generator test status
Communications status
Status and alarm panel status
Computer system status
CW interference azimuth(s)

(c) Sensor software inputs:

A count of the number of real:

- Mode S tracks
- Mode S tracks in coast status (state S1 of 3.4.8.2.2)
- Mode S tracks in All-Call status (state S2)
- Mode S tracks receiving external data (state S3)
- Mode S tracks radar substituted
- ATCRBS tracks
- ATCRBS tracks in coast
- ATCRBS tracks receiving external data
- ATCRBS tracks radar substituted
- Radar tracks
- Delivered messages this scan
- Expired message this scan

- Reply storage overflow flag
- Input message queue overflow flag
- Output message buffer overflow flag
- Active message file overflow flag
- Collimation difference table (3.4.6.12.5)
- Beacon strobe report (3.4.5.8)
- Sensor configuration data
- Sensor error recovery data
- RMMS data requests
- Target Overload Condition (3.3.2.5)

(d) Adjacent sensor inputs:

Status message

3.4.10.3.2 Outputs.- The key outputs shall be the status messages generated once per scan (as a result of the check performed on the input data) and sent to the adjacent sensor or the ATC facilities. The following data shall be included:

(a) Status message (to adjacent sensor):

Sensor ID
Sensor status (normal operation or failure)

(b) Status message (to the performance monitor display, and ATC via the ATC interface):

Sensor ID
Sensor loading statistics (No. of Mode S tracks, No. of ATCRBS tracks, No. of radar tracks)
Status (normal operation, marginal operational or failure) of sensor
Condition(s) that caused the marginal operation or failure state.

(c) Other outputs:

Comm-A message with a CPME address
Comm-C message with a CPME address
Set/reset Mode S lockout or PC-7 for a specified CPME track
Insert test bit for a specified CPME track
Notification of adjacent sensor failure or sensor-to-sensor communications failure
RMMS alarm messages
RMMS status messages
Data extraction status data
TTG data and control
CW interference azimuth(s)
Sensor status signals for ASR-9
Sensor recovery notice message (3.4.10.3.7)

3.4.10.3.3 Checks performed using the CPME.

3.4.10.3.3.1 Initial acquisition.- The CPME shall be unlocked to Mode S at the start of sensor operations and hence will be acquired and placed on the roll-call in the same way as any Mode S aircraft. The discrete address of each CPME shall be entered as a site adaptation message. The performance monitoring function shall monitor the All-Call reply and the transition to roll-call status. At this time, each CPME track shall be labeled as a test track and tagged as primary for downlink communications.

At the end of stochastic acquisition, Channel Management will transition to the use of a normal frame structure. Once acquired on the Mode S roll-call, each CPME will be locked out. This will cause it to respond with an ATCRBS reply to an ATCRBS/Mode S All-Call or to an ATCRBS only All-Call. The ATCRBS replies shall be checked and the resulting ATCRBS tracks shall be labeled as test tracks.

Specific checks made on the Mode S All-Call, roll-call, and ATCRBS replies from the CPMEs are specified below.

3.4.10.3.3.5 Ground initiated Comm-B. - Once every 15 scans, the performance monitoring function shall route a request to the data link processing function for a ground initiated Comm-B message from one of the CPME's. The CPME for this test shall be selected as specified in 3.4.10.3.3.2. The request shall include:

- Type code
- Sender ID (a code assigned to the performance monitor function)
- Mode S ID
- Expiration time
- Air-to-ground message source (RR-18)

When received, the requested Comm-B message shall be checked for conformance to a known test pattern. If the check fails or the message is not received within 5 scans, then this test shall be cancelled, flagged as a fault, and the procedure repeated immediately with a different CPME.

3.4.10.3.3.6 Comm-A - Comm-B. - Once every 15 scans, the performance monitoring function shall request (as specified in 3.4.10.3.3.5) a Comm-A delivery to one of the CPME's. The CPME for this test shall be selected as specified in 3.4.10.3.3.2. The request shall include:

- Type code
- Sender ID
- Message number
- Mode S ID
- Expiration time
- Message data (MA field)
- Tactical Message Subfield (TMS)

Successful delivery of the uplink message shall cause the CPME to indicate the presence of a pilot initiated Comm-B message with the same text as the received Comm-A message. The following checks shall be made:

- Clearing of the B bit
- Received message the same as transmitted

If the check fails, or the test is not completed within 8 scans, the test shall be cancelled, flagged as a fault, and the procedure shall be repeated immediately with a different CPME.

3.4.10.3.3.7 Comm-C - Comm-D. - This check shall be performed once every 30 scans and shall be identical in concept and execution to the procedure specified in 3.4.10.3.3.6. The request shall include:

- Type code
- Sender ID
- Message number
- Mode S ID

Length (four or fewer segments)
Expiration time
Message data (sequence of MC fields)

The following checks shall be made:

Resetting of the DR field
Received Comm-D message the same as the transmitted Comm-C message

The procedure shall be repeated immediately with a different CPME and flagged as a fault if the check fails or no reply is received within 10 scans.

3.4.10.3.3.8 CPME status. - The CPME replies shall be monitored for the presence of an SPI code. When detected, that CPME shall be interrogated to elicit the CPME status message.

3.4.10.3.4 Checks performed on adjacent sensors.

3.4.10.3.4.1 Unused. -

3.4.10.3.4.2 Adjacent sensor status. - Status messages from each adjacent connected sensor shall be monitored. Receipt of a declared failure state shall result in immediate notification of adjacent sensor failure to the network management function.

In the event of loss of the periodic status message for more than 4 consecutive scans, a condition of loss of status message shall be declared for that sensor and reported to the network management function. Checks shall then be made to determine if the loss of the status message was the result of communications failure or an adjacent sensor failure. These checks shall begin after a delay of 2 additional scans from the scan in which loss of status was declared.

The procedure for resolving this ambiguous condition shall be as follows:

- (a) The local sensor shall send a query (Sensor Status Request of 3.4.8.12.2) to all sensors jointly connected to the local sensor and the suspected sensor. The query instructs these sensors to report their current determination of the status of the suspected sensor.

- (b) Response to the queries shall be checked by the performance monitoring function. If at least one jointly connected sensor reports that the suspected sensor is operational, then the suspected sensor shall be declared to be in a state of inferred communications failure. If all joint sensors report the suspected sensor to be in a failed state, then the suspected sensor status shall be declared to be in a state of inferred sensor failure.
- (c) If there are no jointly connected sensors, then the sensor status shall remain as loss of status message. Sensor failure declaration shall not take place unless triggered by the ATC status message described below.
- (d) The adjacent sensor status resulting from the above procedure shall be reported to the network management function.

Declaration of the state of an adjacent sensor or of its communications link shall also be made following receipt of a sensor failure/recovery message from an ATC facility (3.4.8.12.2). This message will contain data fields a) identifying the sensor in question, b) indicating failure or recovery from failure, and c) indicating whether the sensor or its communication link to the local sensor is involved. Information in this message shall always take precedence over the above sensor procedure for determining adjacent sensor status.

3.4.10.3.5 Checks performed on the sensor hardware. - Once each scan, the performance monitoring function shall initiate an I/O operation that causes the contents of the sensor hardware monitor buffers to be transmitted in a sensor overall status message (3.4.10.3.2.(b)), and cleared if no faults were detected. If a fault is detected associated data shall be stored.

3.4.10.3.5.1 Transmitter and receiver checks. - Each of the transmitter powers, receiver gains and receiver noise measurements reported shall be compared to two levels specified as adaptation parameters for that quantity. The receiver noise measurements shall be made only on the standby channel.

Results of these comparisons shall indicate:

Quantity above upper level
Quantity below lower level

An additional check shall be performed for main and SLS, ATCRBS, and normal Mode S transmitter power. This shall consist of comparing the measured power to a maximum level for normal power (specified as an adaptation parameter) to detect a fault which causes continuous transmission in the high-power mode.

A calculation of the ratio of forward to reverse power at the sensor RF port shall be made for each interrogation and over a scan duration determined by either of the two selectable modes of operation:

- a. Full Scan Mode in which the power ratio is monitored over 360° of rotation.
- b. Gated Azimuth Mode in which the power ratio is monitored over a limited azimuth region that is adjustable in width between 0 and 16,384 Au's in increments of 455 Au's and whose leading edge is adjustable over the full range of 16,384 Au's in increments of 455 Au's.

Each of the calculated values of the power ratio shall be processed and compared to the following two levels specified as adaptation parameters:

value below initial alarm level
value below final alarm level

Independent adjustment of the alarm levels shall be provided for each transmitter.

The initial and final alarm levels shall be adjustable over values corresponding to a set of VSWR values ranging from 1.1:1 to 1.8:1 in 0.05 increments. The alarm levels will be calculated using the following equation:

$$\text{Alarm Level} = (P_F/P_T) = ((\text{VSWR} + 1)/(\text{VSWR} - 1))^2$$

The calculated power ratio values shall be compared to the alarm levels in the following manner:

A sampling interval is defined as the number of consecutive power ratio calculations required before a comparison can be made with the alarm levels. This interval shall be adjustable from 1 to 16 in increments of 1.

An alarm count is defined as the number of power ratio calculations within a sample interval that must fall below either level before a fault can be declared for that scan. The alarm count shall be adjustable from 1 to 16 in increments of 1 except that it shall not be possible to obtain an alarm count numerically larger than the sampling interval.

Standby channels shall also verify receiver performance approximately once per scan by inserting Mode A and Mode S replies into the front end directional couplers at -50 dBm, referred to the sensor RF port using the TTG and performance monitor RF hardware, Fig. 3.4.10-1. Each reply type shall be injected at boresight ($\Delta=0$) and crossover ($\Delta=\Sigma$). The correct detection of range, azimuth and all reply data shall constitute verification.

3.4.10.3.5.2 Monopulse azimuth checks. - The off-boresight indication signal for a simulated on-boresight test target ($\Delta=0$) shall be subtracted from 128. The difference shall be averaged over 5(1-32,1) scans, and the result (Δ_m) shall be provided to surveillance processing for use in the monopulse look-up process as specified in 3.4.6.3.2. The absolute value of Δ_m shall also be compared to a limit specified for this quantity and the result used in determining sensor status as described in Table 3.4.10-1.

The off-boresight indication for the simulated off-boresight test target ($\Delta=\Sigma$), averaged over 5(1-32,1) scans, shall be compared to the expected value for this quantity. The expected value is the value obtained when the test was performed

just prior to calibration. 3.4.11.3. The absolute value of the difference between the measured and expected values shall be used in determining sensor status as described in Table 3.4.10-1.

When calibration is performed, a new expected value of the off-boresight indication signal for the off-boresight test target shall be stored. In addition, the new expected value shall be compared to two levels specified for this quantity. Results of the comparison shall indicate:

Expected value below lower level
Expected value above upper level

3.4.10.3.5.3 Radar/beacon collimation check. - Once each scan, the collimation difference table (3.4.6.12.5) shall be checked to determine if it is full. If full, the arithmetic mean of the table values of range differences, RTB, and the arithmetic mean of the table values of azimuth differences, ATB, shall be calculated and the table cleared. RTB and ATB shall then be added to the stored value of the collimation correction range, CCR, and the collimation correction angle, CCA, respectively. The results, redefined as CCR and CCA, shall be checked against limits specified for these quantities. Results of these comparisons shall indicate:

CCR(CCA) above upper level
CCR(CCA) below lower level

The net values of CCR and CCA shall be stored and shall be made available to radar preprocessing (3.4.6.3.6).

Nominal values of CCR and CCA shall be included as adaptation data and shall be used by radar preprocessing until the first computation of RTB and ATB.

3.4.10.3.5.4 System clock checks. - The system clock status word shall be checked for the presence of flags indicating clock errors as listed in 3.4.13.4.

3.4.10.3.5.5 Azimuth register checks. - The azimuth register status field shall be checked for the presence of an azimuth reference mark error flag (3.4.4.7.1.2).

3.4.10.3.5.6 Test Target Generator Tests. - The Mode S performance monitor shall utilize the TTG for unattended performance testing of the sensor on-line and standby reply decoding functions. The TTG tests shall be composed of predetermined test patterns to simulate CPME reply processing in the standby channel, exercise all reply decoder functions not tested by the CPME (paragraph 3.4.14.9), and perform maintenance fault isolation testing of the reply decoders. Once during every frame there shall be a test target Generator (TTG) test period, lasting 450 μ sec. Provision shall be made for enabling the activity of the TTG (3.4.10.3.5.6 and 3.4.14.8) during the TTG test period except in sectors where such scheduling would conflict with the ability of the ATRBS Reply-Reply Correlator to handle peak loading and delay requirements specified in 3.4.5.6.7. The performance monitor shall interface with the TTG as specified in 3.4.14.8. The performance monitor shall examine all reply decoder formatted outputs resulting from TTG injected signals, and test this data for correct

- g) Manual switch settings on the ARIES equipment which may affect the simulation results.
- h) Counts or other indicators of error conditions detected by the software.
- i) The calibration table(s) used to convert offboresight angles to relative Δ vs I signal levels and to I power corrections. Also any other table contents which might vary from experiment to experiment and which could significantly affect simulation results.
- j) The traffic model label data (90.3.6) (however, traffic model data other than the label shall not be recorded).

The contractor shall suggest any other data categories to be recorded which he considers appropriate to carrying out the purpose of the ARIES equipment, and in particular of the data recording function.

90.3.8 Operator commands.- The ARIES operator shall be able to control the operation of the ARIES from the operator's terminal (90.3.2.3.1). At least the following capabilities shall be provided:

- a) The ability to initialize to an arbitrary time on the traffic model as the starting time for the simulation. At the time the simulation starts, the simulated transponder parameters and fruit parameters, as read from the traffic model, shall be identical to those that would have been obtained at that point in time by running the simulation from time zero.
- b) The ability to start the simulation. The simulation shall commence at the first antenna northmark crossing following the issuance of this command.
- c) The ability to stop the simulation. This shall be done in such a way that ARIES can immediately and conveniently be reinitialized as in (a).
- d) The ability to create simulated aircraft from the console. It shall be possible to create them at arbitrary ranges and azimuths. Similarly all other aircraft parameters that are obtained from the traffic model shall also be controllable over their full range.
- e) The ability to drop aircraft created by the operator.

3.4.10.3.5.9 Status and alarm panel checks. - The status and alarm panel status shall be checked for the presence of abnormal temperature conditions (3.4.10.2.5)

3.4.10.3.6 Checks performed on the sensor software. - Provisions shall be made within the appropriate sensor functions (channel management, data link processing, surveillance processing or network management) for the collection and storage of the sensor software status inputs specified in 3.4.10.3.1(c). This data shall be read, once per scan, by the performance monitoring function. Track count data are processed to produce an indication of the fraction of Mode S tracks in status categories S_1 , S_2 , or S_3 , the fraction of ATCRBS tracks not in firmness state 1, the fraction of tracks radar substituted, and the fraction of radar tracks. These normalized values are

This space intentionally unused.

This page intentionally unused.

compared to two levels specified as adaptation parameters for each quantity.

Results of these comparisons shall indicate:

Quantity above upper level
Quantity below lower level

The overflow flags shall be checked for the occurrence of an overflow condition in the corresponding buffer, queue, or file.

The count of delivered and expired messages this scan shall be used to generate an average expired/delivered ratio measured over the past 15 scans. This ratio shall be compared to two levels specified for this quantity in the same manner specified herein for the track count data.

A check shall be made each scan for the presence of ATCRBS beacon strobe report(s) (3.4.5.8) or target overload condition (3.3.2.5). If present, individually or collectively, this information, the strobe report and the target overload condition, shall be included in the sensor status report.

3.4.10.3.7 Decision algorithm. - Once per scan the performance monitoring function shall review all of the performance checks made during that and previous scans and declare that the sensor is in one of the following states:

- (a) Normal operation (condition green)
No abnormal indications
- (b) Marginal operation (condition yellow)
Operation with some limitations
- (c) Failed state (condition red)
Sensor operation ceases

Declaration of sensor status shall include but not be limited to the data presented in Table 3.4.10-1. Values are nominal and shall be adjusted to achieve a desirable balance between the probability of an undetected sensor failure and the false alarm rate for the declaration of sensor failure.

If the ASR-9 interface (3.5.2.4) is present, sensor status shall be made available to that interface in the form of a 1-bit flag. The flag shall be set if the status is green or yellow, and reset if the status is red.

Following recovery from any condition which may have caused the loss of ground-to-air data link messages which were accepted for delivery by the sensor, performance monitor shall generate and make available to the message routing function a Sensor Recovery Notice message (as defined in FAA-RD-80-14).

3.4.10.4 Performance monitor display.

3.4.10.4.1 Description. - The performance monitor display (see 1.2.3) shall include a Plan View Display (PVD) showing all target reports and an alphanumeric tabulation of sensor status reports. Interfaces shall be provided for performance monitor displays at the sensor site and at the ATC facility site. (The number of displays shall be as specified in the contract schedule). The

TABLE 3.4.10-1(a)

SENSOR STATUS DECLARATION DECISION TABLE

Declare condition when
fault duration \geq the
number of consecutive
tests shown

Item	Fault	Yellow	Red
Receiver Gain (Each channel)	Between levels	2	
	Below lower level	1	2
Receiver Noise (Each channel)	Above upper level	1	2
	Between levels (Test to be done only on the standby channel)	2	
Reply Detection (3.4.10.3.5.1)	Reply data not detected, or	2	
	Range error $> \pm 2(1-6,1)$ Ru, or	2	
	Monopulse error $> \pm 6(1-10,1)$ Ru	2	
	(Test to be done only on the standby channel)		
Transmitter Power (Both XMTRS)	Between levels	2	
	Below lower level	1	2
	Normal power above maximum level	2	
VSWR (Both XMTRS)	Above initial alarm level	2	
	Above final alarm level		1
On-Boresight Test Target (3.4.10.3.5.2)	$a < \Delta m < (a+b)$	2	
	$(a+b) < \Delta m $		2
	$a = 2(0-5, 1)$		
	$b = 6(4-10, 1)$		
Off-Boresight Test Target (3.4.10.3.5.2)	$a < \text{MEASURED} - \text{EXPECTED} < (a+b)$	2	
	$(a+b) < \text{MEASURED} - \text{EXPECTED} $		2
	a and b same as for on-boresight		
Collimation Corrections (3.4.10.3.5.3)	CCR above upper level or below lower level	2	
	CCA above upper level or below lower level	2	
System Clock (3.4.10.3.5.4)	One or more error flags set	1	

TABLE 3.4.10-1(b)

SENSOR STATUS DECLARATION DECISION TABLE (CON'T)

Declare condition when
fault duration \geq the
number of consecutive
tests shown

Item	Fault	Yellow	Red
Azimuth Register 3.4.10.3.5.5	Azimuth Reference Error Flag Set	2	
ATCRBS Reply Processor	Beacon Strobe Condition	1	
TTC Tests Results	Digital hardware error	1	
Comm Subsystem Status	Overflow or abnormal message	2	
	Loss of communications	1	
	Modem failure	1	
	Communication line failure	1	
Status and alarm panel	Abnormal temperature condition	1	
CPME Status Message	Declared failure or marginal operation	1	
Sensor Hardware	Loss of redundant element	1	
ATCRBS/All-Call (3.4.10.3.3.4)	Missing - Any CPME	2	
	- All CPME	1	
	Incorrect Azimuth - Any CPME	2	
	Incorrect Range - Any CPME	2	
	Incorrect code or altitude - Any CPME	2	
	Any of the above incorrect for all CPMEs	1	2

TABLE 3.4.10-1(c)

SENSOR STATUS DECLARATION DECISION TABLE (CONT'D)

Declare condition when
fault duration \geq the
number of consecutive
tests shown

Item	Fault	Yellow	Red
Mode S Roll-Call (3.4.10.3.3.3)	Missing - Any CPME	2	
	- All CPMEs	1	
	Incorrect Azimuth - Any CPME		
	Fine Error	2	
	Coarse Error	2	
	Incorrect range - Any CPME	2	
	Incorrect code or altitude - Any CPME	2	
	Any of the above (except fine azimuth) incorrect for all CPMEs	1	2
	Fine azimuth error for all CPMEs	2	
Mode S Communications Missing	- Any CPME	2	
	- All CPMEs	1	
	Failed Comm-A/B check, All CPMEs	2	3
	Failed Comm-A/B check, Any CPME	2	
	Failed Ground initiated Comm-B, All CPMEs	2	3
	Failed Ground initiated Comm-A, Any CPME	2	
	Failed Comm-C/D, B check, All CPMEs	2	
	Failed Comm-C/D, D check, Any CPME	2	
Mode S Tracks in State S ₁ + S ₃	Between levels	2	
	Above Upper level	1	2
Mode S Tracks in State S ₂	Between levels	2	
	Above Upper level	1	

TABLE 3.4.10-1(d)

SENSOR STATUS DECLARATION DECISION TABLE (CONT'D)

Declare condition when
fault duration > the
number of consecutive
tests shown

Item	Fault	Yellow	Red
Mode S Tracks	Between levels	2	
Radar substituted	Above upper level	1	
ATCRBS tracks in Coast	Between levels	2	
	Above Upper level	1	
ATCRBS tracks on external data	Between levels	2	
	Above upper level	1	
ATCRBS tracks Radar substituted	Between levels	2	
	Above upper level	1	
Number of radar tracks	Between levels	2	
	Above upper level	1	
Buffer, Queue or File Overflow flag	Overflow condition	1	
Message Expired/ Delivered Ratio	Between levels	2	
	Above Upper level	1	
# Number of Sensor Tracks	Target Overload Condition	1	

displays shall be connected to the digital side of the modems for the ground communications lines linking the sensor with the served ATC facilities. Operation at the ATC facility site shall be accomplished without modification to the display or the ATC equipment.

3.4.10.4.2 Inputs.- The inputs to the monitor display shall consist of:

- (a) The stream of sensor surveillance and communication output messages as specified in FAA-RD-80-14, intercepted at a digital level of the modems for the ground communication and surveillance data distribution interfaces.
- (b) Commands entered from the keyboard:
 - (1) Display sensor status report
 - (2) Vary range
 - (3) Off-center display
 - (4) Select a subset of targets for display according to target type (i.e., ATCRBS, Mode S, radar) or according to altitude band (i.e., between specified minimum and maximum altitudes) or both.
 - (5) Delete/add identity and altitude tag on Mode S or ATCRBS targets.
 - (6) Display tracked target SFN.

3.4.10.4.3 Outputs.- The output shall consist of a visual display on a CRT whose useful display diameter is at least 14 inches. In addition, there shall be red, yellow, and green lights for sensor status and two audible alarms for red and yellow condition.

The PVD shall have its center at the sensor site and shall have unique symbols for Mode S, ATCRBS, radar, and test (CPME) targets. Reinforced beacon targets shall be shown with a superimposed radar symbol. Radar substitution reports shall be shown with a dot symbol superimposed on the appropriate beacon target symbol. Beacon targets shall be tagged with ID and altitude as selected at the operator's option. The symbols for any target report shall remain visible for a time interval slightly less than the antenna scan period. Alphanumeric data pertaining to sensor status shall be displayed concurrently with the PVD in a reserved region of the CRT. In the event of red or yellow sensor condition, status reports shall automatically be presented in a self-explanatory form.

3.4.10.5 Control of system configuration for maintenance. - Maintenance personnel shall control the configuration of the Mode S sensor as needed to support maintenance procedures using the I/O devices specified in paragraph 3.7.2.4.

3.4.10.6 Remote maintenance monitoring system (RMMS). - The Mode S sensor shall operate with the FAA remote maintenance monitoring system in order to permit performance certification to be accomplished remotely and to minimize the need for on-site maintenance personnel. Included as an integral part of Mode S shall be those extensions to performance monitoring software necessary to remote selected performance data elements, the software necessary to permit certain Mode S control functions to be accomplished remotely, and the interface necessary to communicate the data and control messages to/from the remote maintenance monitoring system. The Mode S sensor shall include a remote monitoring subsystem (RMS) in each channel of the sensor. The RMS shall provide the capability to remotely monitor the operational status and key performance parameters of Mode S sensor equipment, selected environmental building parameters, auxiliary power status, and site security at the facility. In addition, the contractor shall provide the Mode S RMS with all the operational capabilities required by NAS-MD-790 and NAS-MD-792.

Monitored parameters and status data will be transmitted periodically over GFE landlines/TELCO lines via modems to a centrally located data processor, the maintenance processor subsystem (MPS). The MPS (Specification FAA-E-2698) does not form a part of this specification.

3.4.10.6.1 Data gathering and forwarding. - The Mode S performance monitoring subsystem shall gather, store, process, analyze and transmit to the remote monitoring system any or all of the Mode S sensor performance monitor data element(s). This action shall occur following a polled request from the RMS or when triggered by a status transition in any performance monitor data element, (i.e., green to yellow or yellow to red), and on a periodic basis. The polled request messages and replies shall be defined in the RMMS ICD (3.5.7). Selection of the exact performance monitor data elements to be transmitted shall be site adaptable.

3.4.10.6.1.1 RMS Report processing mode. - The contractor shall design and structure the RMS report generation and processing in accordance with the message formats and interactive procedures specified in NAS-MD-790. The message encryption requirements specified on page 3-1 therein are not required. The contractor shall also provide an interface control document (3.5.7) defining the Mode S RMS to MPS interface in accordance with requirements of NAS-MD-790 and 3.5.7.

3.4.10.6.1.2 Alarm report. - Alarm processing and reporting shall preempt and interrupt all other report processing modes. An alarm report shall be generated and transmitted to the MPS on the next poll in accordance with

NAS-MD-790 as soon as the sampled value of one or more monitored parameters exceeds its alarm threshold or frequency of occurrence. Alarm reports shall be processed and transmitted to the MPS as they are detected, on a first-in-first-out basis. Alarm reports shall be retained in storage until they are transmitted to, and acknowledged by, the MPS.

3.4.10.6.1.3 Status report. - Status report requirements shall include various types of requests which can be manually initiated by maintenance personnel for either a specific status or sampling of one or a group of monitored parameter values or a complete certification report. Status reporting shall include the status of the RMS.

3.4.10.6.1.4 Mode S RMS contractor - MPS contractor coordination. - The Mode S sensor RMS contractor shall have prime responsibility for development of Mode S RMS to MPS interface in accordance with requirements of NAS-MD-790 and the requirements of paragraph 3.5.7.1 herein. The Mode S sensor contractor shall perform all programming and coordination required with the MPS contractor, through the Contracting Officer, to assure that the fixed format messages are compatible with the MPS. The FAA is responsible for providing all MPS application software.

3.4.10.6.1.5 Micro-processor/micro-computer programs. - Complete documentation of all micro-processor/micro-computer programs and firmware program specifications for the RMS shall be provided and delivered in accordance with the contract schedule. Documentation shall include a complete description of the program organization and design, including subprogram description, external data formats and internal data formats, shall be furnished as part of the system design data. The documentation shall provide overall information about the total computer program. The design description shall indicate the partitioning of the functional requirements into logically related subsets which are identified with specific subprograms. For each subprogram, a discussion of performance requirements including estimates of program timing and data storage shall be provided. The contractor shall follow the requirements of DOT/FAA/PM-83/37 to document the development, design and testing of the software and firmware for Mode S sensor RMS. The ten development phase document types listed in DOT/FAA/PM-83/37 shall be deliverable items as required in the contract schedule. As part of the software maintenance manual in DOT/FAA/PM-83/37 the contractor shall provide source listings, with clarifying remarks for all programs, as well as flow charts, HIPO diagrams, decision tables, etc. necessary for the representation of the programs.

3.4.10.6.1.6 Programmable alarm limits. - A programmable alarm threshold value for each variable parameter shall be stored in programmable memory.

3.4.10.6.1.7 Pre-alarm filtering. - All monitored parameters shall be subjected to pre-alarm filtering by establishing, for each parameter, a minimum number of occurrences of the error condition detected during a test interval necessary before a fault condition is declared. The number of these pre-alarm occurrences necessary to generate a fault condition shall be dependent on the site adaptable alarm threshold established for each monitored parameter. An alarm message shall be transmitted on the next continuous poll received from the MPS when the fault duration exceeds that which is specified in Table 3.4.10-1 (or the implementation addendum to the

table). If errors are detected for a monitored parameter but the number of pre-alarm occurrences does not reach the fault declaration level, the number of pre-alarms for the parameter shall be included in the next continuous poll from the MPS. If the continued sampling of a parameter which generated an alarm message indicated acceptable operation for a number of consecutive test periods, a return-to-normal (RTN) message shall be transmitted to the MPS for that parameter. The number of consecutive acceptable test periods necessary for a RTN message to be generated shall be one greater than the number which was necessary for the alarm message to be declared for that parameter.

3.4.10.6.2 Interface documents. - The contractor shall design and implement the electrical, mechanical, and data link requirements for Mode S RMS-to-MPS data communication interface according to the requirements of NAS-MD-790 and paragraph 3.5.7 herein.

This space intentionally unused.

3.4.10.6.3 Sensor control functions. - As a minimum, the following functions shall be remotely controlled and be accessible via the on-site local (portable) terminal (3.5.7.2):

- (a) Initial loading and start-up of the sensor
- (b) Modification of sensor site parameters
- (c) Initiation and control of diagnostic procedures
- (d) Reassignment of tasks within the computer subsystem
- (e) Switching of redundant elements from standby to operational status
- (f) Network reconfiguration
- (g) Data extraction of the local sensor.

This space intentionally unused.

This space intentionally unused.

3.4.11 Sensor calibration.

3.4.11.1 Purpose. - This function shall perform the procedures necessary to calibrate range and the off-boresight look-up table for each sensor channel. This table shall be used by channel management (3.4.1.6.5.3.2), surveillance processing (3.4.6.3) and ATCRBS reply correlation (3.4.5.6.1) to convert the 8-bit monopulse off-boresight indication signal supplied by the ATCRBS and Mode S reply processors into an equivalent off-boresight angle. This off-boresight angle shall be added to the antenna boresight angle at the time of measurement to form the measured azimuth for the reply.

3.4.11.2 The off-boresight look-up table. - This table shall contain 256 entries: one for each possible value of the monopulse off-boresight signal. Entry of the table by monopulse signal shall result in an output which corresponds to the off-boresight angle in azimuth units for that value of monopulse signal.

3.4.11.3 Calibration procedure. - The functional relationship defined by the table depends on both the receiver and antenna characteristics. For every antenna/receiver configuration, a different table shall be constructed as part of the process of site installation using a single CPME as a target. The CPME used for sensor calibration (designated as the primary CPME) shall be selected in order to provide the best combination of the following desirable sensor-CPME propagation path features: (a) maximum range, (at least 2000 feet), (b) flat ground along the path, and (c) minimum number of significant lateral multipath objects.

The following calibration procedures, with the exception of steps (a), (b) and (e) in para 3.4.11.3.1, shall be performed automatically under the control of software resident in each channel, when activated by either the Mode S Sensor Control (3.7.5), RMMS or the local RMS terminal. When successful calibration is completed, the final table shall be automatically made available to the appropriate software surveillance functions in that channel and shall, if requested, be made available to the local RMS terminal or RMMS for numerical or graphical display. If calibration is unsuccessful the failure shall be indicated to the Mode S Sensor Control Function, RMMS and the local RMS terminal.

Should the primary CPME be unavailable, any other CPME associated with the sensor may be used for calibration if it has previously been successfully used during the pre-calibration procedures of para 3.4.11.3.1. and during normal operation of the performance monitoring functions of para 3.4.10.

3.4.11.3.1 Pre-calibration procedure. - The following actions shall be taken before commencing the calibration procedure:

- (a) The surveyed azimuth (in azimuth units referenced to true north) shall be obtained for each CPME.
- (b) Appropriate adjustments shall be made to the receiver, monopulse processor and A/D converter so that the A/D value (referred to here as the real part, (rp)) obtained for the on-boresight test target (3.4.10.2.2) is 128.

- (c) The real part value for the off-boresight test target (3.4.10.2.2) shall be determined. This value is referred to as $rp(\Delta-\Sigma)$.
- (d) The antenna position (in azimuth units) corresponding to a real part value 128 shall be determined for each CPME. The pairwise differences between these positions shall be compared to the corresponding differences between the surveyed azimuths. Calibration shall be performed only if agreement within $2(0-5.1)$ Au is obtained.
- (e) The azimuth shaft encoder output shall be adjusted so that the azimuth count in Au corresponding to the real part value 128 for the primary CPME is exactly the surveyed value for that CPME. The adjustment of the azimuth shaft encoder output to one sensor channel shall not effect the output of the encoder to the other sensor channel.
- (f) The off-boresight angle corresponding to $rp(\Delta-\Sigma)$ shall be determined for each CPME using ATCRBS or Mode S replies. The off-boresight angle

-367b-

FAA-E-2716 & AMEND.-2
SCN-15 (Change 21)

This page intentionally unused.

is defined as the surveyed angle of the CPME minus the azimuth shaft encoder count. Calibration shall not be performed if the difference between any pair of off-boresight angles is greater than 1(0-4, 1) Au's.

- (g) The maximum and minimum real part values and associated angles obtainable for each CPME shall be determined using ATCRBS or Mode S replies. The following quantities shall then be defined.

rp_{min} = largest minimum real part
 rp_{max} = smallest maximum real part

3.4.11.3.2 Calibration. The calibration table is a function relating real part values to off-boresight angle. Thus the azimuth of a target can be computed as:

$$\theta = bs + \Delta\theta = bs + C(rp)$$

where

$\Delta\theta$ = target position relative to antenna boresight (in Au),
 $\Delta\theta = C(rp)$

bs = antenna boresight at reply reception time

rp = real part (digitized Δ/Σ)

$C(.)$ = calibration lookup table, indexed by rp .

3.4.11.3.2.1 Step 1 - Data collection. The calibration procedure, using either ungarbled ATCRBS or Mode S replies, shall consist of collecting N=5 (5-20, 1) values of off-boresight angle per real part value (i.e., per table "cell") until both of the following conditions are satisfied:

- (a) at least $P * (rp_{max} - rp_{min} + 1)$ cells are filled, $P = 0.9$ (0.5-1.0, 0.1)
and
(b) there are no more than U consecutive unfilled cells, $U = 4$ (0-20, 1).

The table value $C(rp)$ for a given cell shall be computed as:

$$C(rp) = \overline{\Delta\theta} = \frac{1}{N} \sum_{j=1}^N \Delta\theta_j$$

The spread of the points for a given cell shall be computed as:

$$\sigma_{\Delta\theta} = \max_j \Delta\theta_j - \min_j \Delta\theta_j$$

If $\sigma_{\Delta\theta} > \sigma_{max}$ for a given cell, $\sigma_{max} = 4(2-10, 1)$, then the N replies for that cell shall be discarded and data collection shall be continued until conditions (a) and (b) above are again satisfied. If conditions (a) and (b) cannot be satisfied in $K = 15$ (5-30, 1) minutes, channel failure shall be declared.

3.4.11.3.2.2 Step 2 - Bad Point Rejection. - When data collection is complete, then a curvefit of order 3 shall be computed around each filled cell (in the form $\Delta\theta = f(rp)$) using the closest $M = 4(3-6, 1)$ $(rp, \Delta\theta)$ values on each side of the cell or all values on one side if less than M values exist) obtained during data collection. The residuals, $E(rp)$ where

$$E(rp) = | C(rp) - f(rp) |$$

shall be examined for each cell. If $E(rp)$ is greater than E_{TEST} then the corresponding table value shall be discarded. The process of fitting and discarding table values having too large $E(rp)$ shall continue until:

- a) $E(rp) < E_{TEST}$ for all remaining real part values, where $3(2-10, 1)$, or
- b) Q table values have been discarded, $Q = 6(2-20, 1)$.

In case a) Step 3 shall be performed.

In case b) the calibration procedure shall be restarted with the data collection as in Step 1. If the calibration procedure fails three successive times, channel failure shall be declared.

3.4.11.3.2.3 Step 3 - Interpolation. - In step 3 the calibration table shall be examined for empty cells. Empty cells shall be filled in by third order interpolation using the first $R = 3(2-6, 1)$ valid cell values on each side. (If less than R values exist on one side, use the number existing.)

3.4.11.4 Range calibration. - Each sensor channel shall be range calibrated using a CPME such that the ATCRBS and Mode S range values differ from truth by less than ± 1 Ru. This calibration shall be accomplished with the CPME providing a 1090 MHz signal at a -50 dBm level referred to the RF port.

This space intentionally unused.

This space intentionally unused.

3.4.12 Sensor start-up.

3.4.12.1 Definition and purpose.- Sensor start-up is defined as the activity required to bring the sensor into normal operation after a period of nonoperational status. This function shall provide the capability to bring the sensor into normal operational "on-line" condition after a period of non-operational status or equipment configuration change. The function shall be activated by input command from any of the following control elements and be performed in a automatic sequence.

- (a) Sensor automatic restart (after operational pause) upon command of either the sensor error recovery or performance monitoring functions (restart after replacement of failed elements with standby units or after interruption/restoration of power).
- (b) Remote Maintenance Monitoring System (RMMS) commands generated at the Sector or Center MPS (ATC/NAS) facilities and received via the sensor RS-449 type data input interfaces specified in 3.4.10.6.
- (c) Local commands generated by on-site personnel.

3.4.12.2 Real-time clock synchronization.- The first step shall be to check, and, if necessary, synchronize the sensor system clock (as specified in 3.4.13.2).

3.4.12.3 Program loading.- The next step shall be the loading of the system operational program from the sensor system input device. This program will have been previously generated by the sensor programming support facility (Appendix II), or the sensor, and will include a specification of all of the site dependent parameters defined as site adaptation data in 3.6.3.

3.4.12.4 Site adaptation modification.- It shall be possible for an operator to modify, via the RMS/MPS (3.5.7), any of the site adaptation parameters from the sensor maintenance I/O device. If the sensor is in operational status, it shall not be necessary to take the sensor off line to modify these adaptation parameters. The program adaptation parameters for the sensor programs shall be stored in a central location. When program adaptation parameters are changed each parameter change shall access one storage location.

3.4.12.5 Not used.

3.4.12.6 Performance monitoring check.- A check shall be made of the acquisition and track initiation of the CPME Mode S and ATCRBS tracks. After CPME acquisition, the normal operation of the performance monitoring function shall begin. Sufficient time shall be allowed for two complete cycles of the performance monitor checks as specified in 3.4.10.

3.4.12.7 Initial acquisition of Mode S aircraft.- Initial acquisition of Mode S aircraft shall be accomplished using the stochastic All-Call acquisition feature specified in the Mode S National Standard. Stochastic Mode S only All-Calls shall be transmitted at a rate sufficient to permit 4(4-8, 1) interrogations per 3 dB beam dwell. The listening window at each azimuth shall correspond to the normal sensor operating range as specified in the ATCRBS/radar range mask (3.4.8.3.6). The initial stochastic probability specified shall be a site adaptation parameter selected from the set [1/16, 1/8, 1/4, 1/2]. This value shall be used in the stochastic acquisition interrogations for $M = 2(2-10, 1)$ scans. After M scans at the initial probability, the next higher probability shall be used in the interrogation for the next M scans. The process shall be repeated until the above set of probabilities has been exhausted.

Ungarbled replies received in response to each stochastic interrogation shall be used to initiate Mode S tracks. These Mode S aircraft shall be discretely interrogated on the next and subsequent scans.

3.4.12.8 Normal operation with Mode S lockout.- Successful completion of the performance monitor checks specified in 3.4.12.7 and the acquisition of the Mode S track file shall result in the commencement of normal sensor operation. Notification of operational status shall then be provided to adjacent sensors and served NAS facilities by the routine sensor status message each scan as specified in 3.4.10.3.2. All ATCRBS and Mode S reports obtained by the sensor before commencement of normal operation shall be discarded by the sensor.

This space intentionally unused.

3.4.13 System timing.

3.4.13.1 Description.- The sensor shall include a real-time system clock which provides both a time-of-year (TOY) clock and a station time clock. The TOY clock shall provide time of year referenced to universal time clock (UTC) time. The station time clock shall provide time information for sensor control.

3.4.13.2 Time-of-year (TOY) clock.- The TOY clock shall visually display time of year in decimal digits. It shall display the day of year counting from one through 365 or 366 as appropriate, the hour of day through 24, the minutes and the seconds. The TOY clock shall be automatically referenced to UTC time with an accuracy of ± 2.5 msec. The TOY clock shall consist of two independent units, each functionally equivalent, with each unit providing time to each front end channel.

3.4.13.2.1 TOY clock buffered outputs.- The TOY clock shall provide buffered outputs at which the time code shall be available. The outputs shall consist of days, hours, minutes, seconds, and seven bits of fractions of seconds ($1/128$ second = LSB). These outputs shall be used as required for time tagging (a) reply data by the Mode S and ATCRBS reply processors and (b) data recorded by the ARIES.

In addition, time-of-year shall be transferred to the channel management function when requested (3.4.13.5).

3.4.13.2.2 Time-of-day (TOD).- The time-of-day code is a subset of the time-of-year code. It provides 24 hour clock time to a precision of $1/128$ th of a second.

3.4.13.3 Station time clock.- The station time clock shall be driven by a 16 MHz signal derived from a frequency source which is stable to one part in 10^8 over any 12 second period, and that has an accuracy of one part in 10^5 . It shall include a register in which 23 bits of binary coded time are available having an LSB of 62.5 nsec. This gives the station time clock a time modulus of 524.288 ms.

3.4.13.3.1 Time unit word.- The most significant 15 bits of the station time clock shall be defined as the time unit word. The LSB of time unit time shall be $16 \mu\text{sec}$. The time unit word shall be transferred to the channel management on request (3.4.13.5) and shall be made available to any function as required by the sensor implementation.

3.4.13.3.2 Range unit word.- The least significant 16 bits of the station time clock shall be defined as the range unit word. The LSB of the range unit word shall be 62.5 nsec. The range unit word shall be used to drive the transmission control register of the transmitter/modulation control function, and shall be made available to any function as required by the sensor implementation.

3.4.13.4 Performance monitoring function inputs.- The TOY and station time clocks shall contain logic which shall determine the following conditions and set a bit for each in the hardware status buffer (3.4.10.2):

- (a) Loss of external time synchronization.
- (b) Error in the station time clock or its oscillator.

The monitoring logic shall provide switching to select a non-failed TOY clock input. An indication of the occurrence of a selection based on a detected failure shall be provided in the hardware status buffer.

3.4.13.5 Data transfer to channel management.- When requested, the system timing function shall transfer various time words and antenna pointing angles to the channel management function. The response shall be as defined below:

(a) Response to time request

Time of Year (3.4.13.2)

Upper 16 bits of the Station Time Clock (3.4.13.3)

(b) Response to azimuth request

Azimuth - This shall be a 14 bit word representing the antenna pointing angle referenced to true north (azimuth word originates in the AARTU; see 3.4.4.7.1 and Fig. 3.4.4-1).

North Mark Time - This shall be a 15 bit word that contains the lowest order 15 bits of the time-of-year clock at the time that the azimuth reference pulse occurs.

3.4.13.6 Standby power.- Standby power shall be provided to the TOY clock if required to meet the recovery specification of 3.9.

3.4.13.7 Start and restart procedure.- The contractor shall develop and deliver the detailed method, procedures, and equipment including the receiving system for the external standard, for start-up and restart in the event of a TOY clock failure or complete loss of sync. The method developed shall include at a minimum the method for initially and subsequently setting the TOY clock to the proper time.

This space intentionally unused.

3.4.14 Test target generator.- The test target generator shall be configured as built-in equipment and shall provide the means to periodically verify correct performance of the modulation control unit, the AARTU, the receiver, the ATCRBS reply processor and the Mode S reply processor digital hardware. When the TTG is in use, normal system interconnection shall be interrupted. Means for software controlled high speed (1.0 μ sec) switching between normal and TTG connections shall be provided. See Fig. 3.4.14-1.

- # The standby channel TTG shall be used for system verification of the standby channel. It shall interface with the transmitter/receiver monitor associated with the standby channel (3.4.10.2.1) to provide RF reply signals (ATCRBS and Mode S) at crossover and boresight. #

The test target generator shall provide inputs to the processor unit representing quantized Mode S and ATCRBS replies. These inputs shall be digital signals representing the receiver's video pulse quantizer outputs, and 8-bit data words representing the monopulse video signal level. The TTG shall also supply data representing interrogation and processor control blocks normally received from the computer subsystem and simulated ACP and ARP signals normally received from the antenna's azimuth pulse generator.

A TTG manual mode shall be provided in which replies are injected at a 100 Hz rate.

3.4.14.1 Reply data channels.- The TTG shall provide reply data channels for output of the following signals:

- | | |
|---|----------|
| (a) ATCRBS Quantized Sum Video (QIA) | - 1 bit |
| (b) Mode S Quantized Sum Video (QID) | - 1 bit |
| (c) Quantized Sum Positive Slope (QIPS) | - 1 bit |
| (d) Quantized Sum Negative Slope (QINS) | - 1 bit |
| (e) ATCRBS Quantized SLS (QSLSA) | - 1 bit |
| (f) Mode S Quantized SLS (QSLSD) | - 1 bit |
| (g) Chip Amplitude Comparison (CAC) | - 1 bit |
| (h) Monopulse Video Data | - 8 bits |

3.4.14.2 Reply data memory.- The TTG shall supply storage for the data of 3.4.14.1. This storage shall provide a 16 x 4K memory as a minimum. This memory shall be capable of being read at a rate of up to 16.552 MHz with the actual rate at which the data is read being defined by an externally generated clock.

3.4.14.3 Processor control.- The TTG shall include a processor control function. This function shall provide storage for interrogation and processor control blocks and shall output these blocks as simulated data from the computer subsystem. These control blocks shall include data defined in 3.4.2.1 as required by the test scenario being run.

- # 3.13 Documentation.- The contractor shall provide all necessary services and materials required to develop, prepare, and deliver to the Government the documentation specified herein, in accordance with the formats, quantities and submittal schedules specified by the contract schedule. All documentation specified herein shall be maintained current throughout the contract life cycle reflecting the current Government approved version of each document. Documents which have been formally accepted by the Contracting Officer and require revision as a result of a Government approved engineering change request (ECR) shall be subject to the same requirements as those imposed on the initial submittal with regard to format, quality and quantities. Specifications subject to change as a result of a Government approved ECR shall be revised and processed in accordance with the requirements specified by paragraph 3.3 of MIL-STD-490. Engineering drawings and associated lists subject to change as a result of a Government approved ECR shall be revised and processed in accordance with the requirements specified by Chapter 500 of DOD-STD-100. All other documents subject to change (e.g. plans, manuals, reports or procedures) shall be processed in the form of replacement or change pages or by revision of the entire document when more than 50 percent of the document is affected by the revision.

All documents developed, prepared, updated or delivered shall be identified in accordance with the following requirements:

- (a) Technical documents shall be numbered and dated on each page. The identification number, with the date below it shall always appear at the top of the page opposite the binding edge. The number shall not contain more than fifteen characters, excluding dashes and revision letter. Revision letters, starting with "A" for the first revision, and assigned alphabetically for each succeeding revision, shall follow the document number. Letters I, O, Q, S and Z, can be confused with numerals and therefore shall not be used.
- (b) Engineering drawings and associated lists shall be identified in accordance with the requirements specified by chapter 400 of DOD-STD-100.

The legibility and clarity of all delivered reproducibles shall be in accordance with the requirements of paragraph 3.9 of DOD-D-1000. The media (microfilm or diazo prints) selected by the contractor shall comply as a minimum with the following:

- (c) Microfilm shall comply with the requirements of MIL-M-9868, as applicable to Type II, Class 3, Diazo type microfilm.
- (d) Diazo prints shall comply with the requirements of MIL-D-5480, as applicable to Type I, Class 2 and Type II, Class 2 diazo prints. #

All documents shall be prepared using correct English and a minimum of abbreviations and acronyms. Correct spelling (e.g. "through" instead of "thru") and punctuation shall be used in clear, direct sentences. Effective and unambiguous communication of the intended information shall be the goal of each document.

3.4.14.4 TIG data input.- The reply data memory of paragraph 3.4.14.2 and the processor control memory of paragraph 3.4.14.3 shall accept data inputs from either manual entry using the operator's control function, automatic entry using a data input device, or automatic entry under control of performance monitor software. The data input device shall be part of the TIG equipment but may be external to the TIG electronics unit. The memory being loaded shall be defined by controls on the operator's control function.

3.4.14.5 Antenna ACP and ARP simulation.- The TIG shall provide simulated ACP and ARP outputs meeting the requirements of 3.4.4.7.1.1. There shall be 16384 ACP pulses for each ARP pulse with the ACP frequency set to simulate the antenna scan rate.

3.4.14.6 Operator's control function.

3.4.14.6.1 Controls.- The Operator's control function shall supply, as a minimum, controls required to:

- (a) Select either manual or automatic data input.
- (b) Select the memory being programmed or read.
- (c) Address memory locations for manual programming or readout.
- (d) Specify data being manually loaded into memory.

3.4.14.6.2 Indicators.- The operator's control panel shall supply, as a minimum, indicators required to display the selected memory data.

3.4.14.6.3 Test scenarios.- Specific test scenarios shall be provided for fault isolation of off-line processor faults to the Least Replaceable Unit (LRU).

3.4.14.7 Modes of operation.- The TIG shall operate in either of the following modes:

- (a) Automatic: under control of performance monitor software or local data input device.
- (b) Manual: under control of the TIG operator control function.

3.4.14.8 TIG operational use.- The TIG shall normally be used for unattended testing of all sensor reply processing decoding functions. Specific sets of reply data patterns shall be injected during 450 μ sec time periods. These TIG test periods shall be scheduled by channel management once per frame and as required when sufficient time is available during roll call periods within the frame (3.4.1.2.2). Provision shall be made for enabling the activity of the TIG (3.4.10.3.5.6 and 3.4.14.8) during the TIG test period except in sectors where such scheduling would conflict with the ability of the ATCRBS Reply-Reply Correlator to handle peak loading and delay requirements specified in 3.4.5.6.7. During TIG test periods interrogations (over a antenna system) and surveillance processing of any test replies shall be inhibited.

The TTG shall also be available for use when required (manual mode) for fault
isolation of standby receiver/processor LRU's by on-site maintenance personnel.

The performance monitor function shall automatically control the TTG processing as #
follows for each scheduled test cycle:

- (a) load the TTG memories with the required test reply and control block information for the test to be performed.
- (b) connect the equipment under test to the TTG.
- (c) transfer the reply and control data to the equipment under test.
- (d) return the equipment under test to normal connections.
- (e) verify that the equipment under test has processed the test input correctly.

The process shall be automatic under control of the performance monitor software.

3.4.14.9 Functions tested. - The TTG reply test patterns shall include, as a minimum, test patterns which exercise the following functions:

- (a) ATCRBS phantom declaration and elimination (3.4.5.3.1.1)
- (b) ATCRBS monopulse average updating (3.4.5.3.2.4)
- (c) ATCRBS clear and garbled reply detection (Tables 3.4.5-1 and 3.4.5-2)
- (d) Mode S preamble detection (3.4.4.3)
- (e) Mode S message bit processor (3.4.4.4)
- (f) Mode S monopulse processor (3.4.4.5)
- (g) Mode S message decoding (3.4.4.6)
- (h) ATCRBS reply decoding of four overlapped replies (3.4.5.3.2.1)
- (i) ATCRBS reply decoding overload condition detection (3.4.5.3.2.8)

This space intentionally unused.

3.5 Interface requirements. - The Mode S interfaces allow Mode S to use, provide or exchange information with other systems. Some of this information is unsophisticated (e.g. azimuth pulses) and some is quite sophisticated (e.g. sensor debug commands). The contractor shall use internal message addressing consistent with the sensor function requirements (data link, network management, data dissemination, radar interface, etc.), necessary to support the data to be exchanged with multiple sensor users (ATC, non-ATC, etc.) on their interfaces. Each Mode S sensor shall be capable of interfacing with a number of other systems or subsystems:

- Antenna arrays and antenna pedestals
- Radar (primary) equipment
- NAS ATC facilities (including Terminal and En Route) and Non-ATC Data Link users
- Sensor Programming Support Facility
- Aircraft reply and interference environment simulator (ARIES)
- Remote maintenance monitoring system (RMMS)

All interface connections between the dual channel Mode S sensor and the other systems shall be located in wall mounted junction boxes except the ARIES interfaces which may be located in an equipment cabinet. All interconnecting cables, terminating connectors, and junction boxes at the Mode S sensor site shall be provided by the contractor except those specified in 3.15.2.2 as Government furnished.

The principal characteristics of these interfaces are set forth here.

3.5.1 Antennas. - The Mode S sensor shall be designed to interface and operate with minimal adjustment with several antennas. Rotation rates of from 5 to 15 rpm shall be accommodated as well as a nominal 3 dB beamwidth of 2.4° . Each antenna system with which operation must be achieved will have sum, difference, and omni channels, for monopulse angle determination and sidelobe suppression.

The specific antennas to be used are the:

- (a) ATRBS open array antenna, as specified in FAA-E-2660.
- (b) Enroute antenna array group, as specified in FAA-ER-240-35b.

3.5.1.1 Azimuth pulse generator modifications. - Collocated radar systems presently equipped with azimuth pulse generator (APG) systems supplying 4096 azimuth change pulses (ACPs) and one azimuth reference pulse (ARP) for each 360 degrees rotation of the antenna shall be modified to produce the signals necessary for Mode S operation, according to the contract schedule. The contractor shall provide the equipment and documentation, to conform to FAA Orders 1320.33 and 6032.1, to make the changes to provide 16,384 Azimuth Unit (Au) pulses along with the single azimuth reference pulse for each 360 degrees of antenna rotation. Two separate outputs shall be provided for each APG. One shall be 16,384 equally spaced Au's per scan for use with Mode S and the second shall provide 4,096 equally spaced ACPs for use with the present site equipment. The leading edge of the ARP shall occur midway between the leading edges of the 16,384 equally-spaced azimuth pulses and shall be adjustable to any single reference point in the antenna rotation. The processed azimuth pulses shall have the same characteristics as those in the present equipment and shall define, by pulse count, the angular position of the center of the radar beam with an angular error not to exceed ± 0.022 degrees for the 16,384 pulses and ± 0.088 degrees for the 4096 pulses. The equipment and documentation is to be provided to the Government in

sufficient time for the Government to install it in the system prior to the arrival of the Mode S sensors.

3.5.2 Radar (Primary) interface. - The Mode S sensor shall be capable of accepting radar surveillance data as required by the radar system specified in the site delivery schedule. The contractor shall, however, provide the ability to adapt any Mode S sensor radar interface to any radar system specified by the Mode S delivery schedule. This process shall be accomplished by addition/deletion and/or replacement of sensor's lowest replacement units. The radar surveillance data may be provided by any of the following systems:

- #
- (1) Not used
 - (2) CD-2, Common Digitizer, Model-2
 - (3) Not used
 - (4) Airport Surveillance Radar (ASR-9)
 - (5) Not used
- =

The contractor shall design all Mode S external interfaces required as described below and submit external interface control documentation as ICD's for Government approval in accordance with the contract schedule (3.13.1.9).

- # 3.5.2.1 Common digitizer interfaces. - When interfaced to a common digitizer, the CD will perform the search and weather digitizing functions. Search, Search Real-time Quality Control (RTQC), status, map, and strobe data shall be transferred from the CD to the Mode S sensor. The Mode S sensor shall perform radar-beacon reinforcement and disseminate common narrow band radar, beacon, weather, and surveillance data to users.

The target reports, available to the sensor within 3/64 of a scan from the time of reported azimuth, shall be correlated with beacon reports and coasted tracks as specified in 3.4.6.12. Any primary radar returns arriving after this time shall be passed along to ATC facilities without radar-beacon correlation.

- # 3.5.2.1.1 Not used. -
- =

This space intentionally unused.

3.5.2.2 CD-2 Interface. - The contractor shall provide in each Mode S channel the capability to receive radar data from the CD-2. The electrical and mechanical characteristics of the communications interface shall conform to EIA-STD-RS-ABC as specified in 3.5.8.2. The Mode S contractor shall design and provide modification kits for modifying the CD-2 to provide the following:

- (a) Transfer of data, from the CD-2 to the Mode S, required to support sensor functions (like the surveillance processing formatting function).
- (b) Any modification required to support the automatic selection of the ATC-BI Backup Mode in the event of a sensor failure.
- (c) Data transmission from the CD-2 to the Mode S at a minimum rate of 0.5 megabits per second.
- (d) The protocol necessary to transmit data specified in item (a) above from the CD-2 to the Mode S. Only one report (weather, status, etc.) shall be allowed to be transmitted within a message frame. No data shall be retransmitted. Error detection for messages shall be 16-bit CRC, or better, for each message frame. The format shall be defined by the contractor and incorporated within the Mode S system only after approval has been obtained from the Government.

3.5.2.2.1 Not used. -

This space intentionally unused.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-4

-382-

This page intentionally unused.

3.5.2.3 Not used.-

3.5.2.4 Airport Surveillance Radar (ASR-9).- The contractor shall provide an interface that complies with the ASR-9 ICD provided by the government as described in item (c) below. The Mode S sensor shall automatically select the on line ASR-9 channel. Under certain circumstances the ASR-9 may provide surveillance data simultaneously on both channels. The automatic selection of the on line ASR-9 channel shall have a manual override. The ASR-9 contractor will provide the following:

- (a) Radar reports from the ASR-9 within 3/64 of a scan from the time of reported azimuth. Following the completion of the tasks defined in 3.4.6.12; radar only reports, beacon only reports, and radar/beacon merged reports shall be retransmitted to the ASR-9 where radar only reports shall be correlated from scan to scan. In addition, the ASR-9 shall transmit all surveillance data to ATC facilities.
- (b) Weather messages from the ASR-9 will be transmitted directly to ATC facilities. The Mode S system when operating with the ASR-9 will not receive or transmit weather messages to ATC facilities.
- (c) Interface control document specifying the ASR-9 to Mode S interface, the Mode S interface to the ASR-9, and ATC-BI Backup Mode of Mode S with ASR-9.

3.5.2.4.1 Mode S/ASR-9 Interface Characteristics.- This interface is specified in the ASR-9 ICD as specified in 3.5.2.4.

This space intentionally unused.

Asynchronous Balanced Mode (ABM) - Under such procedures, each of the two stations on point-to-point link is a combined (primary and secondary) station. As appropriate, either of the two stations can take on the primary role (send commands), causing the other to take on the secondary role (send responses).

FAA-E-2716 & AMEND.-2
SCN-15 (Change 21)

-384-

3.5.2.5 Not used.-

This space intentionally unused.

Fig. 3.5-5 Not used

3.5.3 NAS facilities interfaces and communication link. - The principal interfaces to the Mode S surveillance and data-link network are to computers located in the NAS facilities. The Mode S sensor shall maintain two types of digital interfaces: a communication interface and a surveillance interface from sensor to ATC.

The sensor shall have up to six surveillance links and up to six communication links. In general, link designs shall be compatible with service to:

- NAS Terminal Automation System
- NAS En Route Automation System
- Non-ATC Users (Weather Communication Processor)

Each link shall be served by a common input/output port. Each port shall provide interface capabilities as specified in 3.5.8.1. Port input/output capability shall be such that each port shall provide the capability to transmit data, receive data or transmit and receive data simultaneously on up to six 9,600 bit per second modems. Output data shall be equally distributed among the modems that are in use on each port. Each port shall have the ability to select internal or external clocking. When external clocking of sensor data is provided, the port modem interfaces shall transmit data, receive data, or transmit and receive data simultaneously at rates up to 56,000 bits per second. The total simultaneous transmit and receive data rate is not required to exceed 56,000 bits per second in either direction per port. The port shall be designed such that the link protocol is generated and controlled by software or firmware processes.

The surveillance link is intended to support a one-way transport. Therefore only one set of the six sets of receive signals (status, control, clock and data), for the port modem interfaces (3.5.8.1), are required to be implemented for each surveillance port. If only one set of these receive signals are provided for each port, it shall be possible to automatically switch these receive signals to any one of the six modem connections to allow performance monitor tests such as local loopback. The port shall still provide the status signals to allow the sensor to continuously detect modem lines that are unavailable.

3.5.3.1 ATC communication link. - Each communication link with the ATC facilities shall be a two-way link. The number of interfaces will be specified in the contract schedule.

The messages, and their formats, to be transmitted and received on this link shall be as specified in FAA-RD-80-14. Link control procedures (link layer) shall be as specified in FAA-RD-80-14.

The use of this link by sensor functions is specified in other paragraphs herein.

3.5.3.2 Non-ATC communications link.- Each communications link with NAS users of Mode S data link services, other than ATC facilities, shall be one or more two-way links between the sensor and the non-ATC users. No surveillance link is to be included. The number of interfaces will be specified in the contract schedule.

The messages, and their formats, to be transmitted and received on this link shall be as specified in FAA-RD-80-14. Link control procedures (link layer) shall be as specified in FAA-RD-80-14.

The use of this link by sensor functions is specified in other paragraphs herein.

3.5.3.3 Surveillance link.- Each surveillance link with the ATC facilities shall be a one-way link. The number of interfaces will be specified in the contract schedule.

Provision shall be made for storing the peak number of messages associated with the maximum surveillance data rate and the minimum link data rate to prevent loss of data. Regardless of this storage of peak messages, the sensor is still required to comply with any special message timing and performance requirements specified in FAA-RD-80-14.

The messages and formats are specified in 3.4.6.14.2. The link protocol (link layer) shall be as specified in FAA-RD-80-14. FAA-RD-80-14 may have more than one surveillance link protocol specified, the choice of any one surveillance link protocol for the sensor shall be a site adaptable parameter. The means to change to a different link protocol for future applications shall be provided without hardware modifications.

The use of this link by sensor functions is specified in other paragraphs herein.

3.5.4 Not used.

3.5.5 Sensor-to-support facilities communications link.- A sensor data path shall be provided for the interchange of data with the programming and Mode S sensor support facilities. This interface shall be a manual dial-up, two-way, 4800 bps digital communications link as specified in 3.5.8.1. It shall provide for the transmission of extraction data (3.8) from a sensor to support facility or adaptation data and programs from the support facilities to the sensor. The contractor shall provide the necessary hardware and software for a circuit connection to be initiated from either the sensor site or support facility and shall operate without impacting real-time sensor operation. Data link control procedures shall be as defined in ANSI X3.66.

The functional capability of this link shall be completely controlled by the RMS/MPS.

3.5.6 ARIES interface.-

3.5.6.1 ARIES RF interface.- An RF power splitter shall be provided in the main transmitter forward peak power monitor (figure 3.4.10-1) for coupling interrogation waveforms to the aircraft reply and interference environment simulator (ARIES - Appendix IX). RF input combiners shall be provided for coupling simulated target replies from the ARIES unit into the sum, difference and omni channels of the sensor. The gains of the ARIES RF channels shall be such that a simulated target at a range of 1.0 nmi and on boresight will appear as a signal at -20 dBm referred to the Mode S sensor sum channel RF port. The RF interface shall be provided using SMA type connectors in each sensor channel.

3.5.6.2 ARIES digital interface.- Provision shall be made for the ARIES to access the sensor TOY clock (3.4.13.2.1) and ACP/ARP data. The sensor TOY clock to ARIES interface shall be a parallel interface which provides all TOY clock data and synchronization to the ARIES. The sensor shall provide ARIES with antenna face and channel status indicators. One status indicator shall signify which antenna face is operating in the back-to-back configuration. One status indicator shall signify which channel is on-line and which is on standby. APG data in the form of ACP's and ARP's shall be provided to the ARIES from the sensor. The sensor shall also be capable of accepting ARIES simulated ACP's and ARP's.

All sensor to ARIES digital signals shall be RS-422 capable of driving at least 50 feet of cable and be made available in each sensor channel using connectors.

3.5.7 Remote maintenance monitoring system (RMMS).- The interface between the Mode S sensor and the RMMS maintenance processor subsystem (MPS) shall be provided by the Mode S sensor Remote Monitoring Subsystem (RMS). The Mode S RMS shall perform facility monitoring, data acquisition and alarm determination, and reporting functions in compliance with all operational requirements of NAS-MD-792. The Mode S RMS shall also be capable of interfacing with a local (portable) terminal.

3.5.7.1 Mode S RMS-to-MPS interface.- The interface and communications between the Mode S sensor RMS and the RMMS maintenance processor subsystem (MPS), shall be governed by NAS-MD-790. However the requirements of FAA-E-2716, paragraph 3.5.8 shall be used in place of the electrical and mechanical requirements of NAS-MD-790, Section 2. The contractor shall provide for synchronous communication between the Mode S RMS and the MPS. The communication interface between the RMS and MPS shall be capable of transmitting and/or receiving data simultaneously at selectable data rates of 2400, 4800, and 9600 bits per second. The contractor shall provide an interface control document (3.12.1.9) in sufficient detail to completely describe the information transfer and the functional operational use of the communication link between the RMS and MPS in accordance with NAS-MD-790. The sensor channels shall not be switched between the modem interface. Instead, the channels shall each have their own link addresses and be tied to the modem interface in a multi-point network configuration.

3.5.7.2 Mode S RMS to local terminal interface.- The contractor shall interface the RMS to a local (portable) terminal. Data exchange shall be asynchronous using as a minimum the Code for Information Interchange requirements of ANSI X3.4-1977. Data rates of 1200, 2400, 4800, 9600, and 19,200 bps shall be selectable. Provision shall be made for directly connecting the terminal to an EIA-STD-RS-ABC port in accordance with paragraph 3.5.8 herein. The local (portable) terminal interfaced to the RMS shall be the same I/O device referred to in paragraph 3.8.3.1 as a GFE data extraction video display. The contractor shall provide an Interface Control Document defining the Mode S RMS-to-local terminal interface.

This interface may be implemented with two communications connections, instead of one with sensor channel switching. If this dual connection is provided, it shall be to allow independent control of a channel that is not connected to another channel. Under this dual connection implementation, the local terminal interface may terminate at the equipment cabinet instead of at the sensor junction box.

With the dual connection for the local terminal, all commands and uses of the terminal for the sensor and its channels, shall work from the connection to either channel, unless the channel to channel connection has failed or is otherwise unavailable. This allows full control over and interaction with the sensor and the sensor channels without the need to switch connections.

If the interface uses one communication connection, the interface shall be kept switched to an active sensor channel. When there is no active sensor channel, the interface shall be kept switched to an active sensor control function. When there is no active channel and both channels sensor control functions are active, this interface switch shall only be switched when there is a failure involving the sensor control function currently connected to the interface.

3.5.8 EIA-STD-RS-ABC interfaces.- All EIA-STD-RS-ABC interfaces specified herein shall be implemented as specified in 3.5.8.1 and 3.5.8.2.

3.5.8.1 Modem interface.- Sensor interfaces connected to other processing equipment through a Modem shall conform to a full implementation of EIA-STD-RS-ABC with the exceptions and options as specified below.

The following circuits of EIA-STD-RS-ABC shall be made operational:

<u>Circuit</u> <u>Mnemonic</u>	<u>Circuit</u> <u>Name</u>
SG	Signal Ground
DM	Data Mode
SD	Send Data
RD	Receive Data
TT	Terminal Timing
ST	Send Timing
RT	Receive Timing
RS	Request to Send
CS	Clear to Send
RR	Receiver Ready
LL	Local Loopback
RL	Remote Loopback
TM	Test Mode

All category I circuits shall be implemented as balanced circuits. The sensor shall be implemented as the Data Terminal Equipment (DTE) device for these interfaces.

3.5.8.2 Processor interface.- Sensor interfaces connected to other processing equipment shall conform to a full implementation of EIA-STD-RS-ABC if required for proper operation of sensor. If a subset of EIA-STD-RS-ABC is selected by Mode S contractor, this subset shall be subject to government approval. The implementation of EIA-STD-RS-ABC circuits Test Mode, Local Loopback and Remote Loopback are not required.

All category I circuits shall be implemented as balanced circuits. The sensor shall be implemented as the Data-Circuit Terminating Equipment (DCE) device for these interfaces.

3.5.9 Special operation with ASR-9 interface.- There is a special consideration for sensor operation with the ASR-9 interface as specified in 3.5.2.4 and the surveillance link interface as specified in 3.5.3. The consideration is that the sensor need not transmit data to the ASR-9 when it is also transmitting data out of the surveillance link(s). If the sensor is implemented with this restriction on data transmission, any one of the following operational states shall be selected through site adaptation.

- (a) Transmit data to ASR-9 as required by 3.5.2.4 and transmit no data out of surveillance link(s).
- (b) Transmit data out of surveillance link(s) as required by 3.5.3.3 and transmit no data to ASR-9.
- (c) Transmit data to active path (ASR-9 or surveillance link(s), whichever is selected, but not controlled, by SDS) to support Mode S/ASR-9 backup mode as specified in 3.7.7.

3.5.10 Remote control point communications interface.- This interface shall operate at 1,200, 2400, or 4,800 bits per second two way. The operational speed of the interface shall be site adaptable for the sensor and manually selectable for the remote control point. The gross bit rate across the interface shall be up to 4,800 bits per second.

3.5.10.1 Remote control point physical layer.- The modem interface for the sensor shall be as specified in 3.5.8.1. The interface shall be kept switched to an active sensor control function. When both channels sensor control functions are active, this interface switch shall only be switched when there is a failure involving the sensor control function currently connected to the interface. The modem interface for the remote control point shall be as specified in 3.5.8.1 or shall be EIA-RS-232C.

3.5.10.2 Remote control point data link layer.- The link protocol will prevent messages from being acted upon in error. The link shall be asynchronous, with characters transmitted as follows: one start bit, seven data bits, one parity bit, and one stop bit. When the sensor receives a command it shall return a query to the user indicating the received command and requesting an acknowledgment (ACK) or negative acknowledgment (NACK). This ACK or NACK shall require two to four operator keystrokes using at least two different keys not adjacent to each other on the keyboard.

3.6 Sensor program adaptation.- Sensor program adaptation refers to the site-peculiar data (general environment and system capacities) which will allow a single master program to be used in the generation of the functional program for a particular sensor, and to ensure that the system is responsive to operational needs.

3.6.1 Master program.- The contractor shall provide all computer programs as required in 3.4. The basic program, including all algorithms and procedures that are common to all sensors, is defined as the master program. This program shall serve as the baseline for the site adapted programs that will be generated for use at individual sensors. The contractor shall deliver a master program, on a transportable storage medium, with each sensor.

3.6.2 Sensor site program.- The site adapted master program that is generated for each sensor is defined as the sensor site program. The contractor shall deliver a sensor site program, on a transportable storage medium, with each sensor. This program shall be site adapted to local conditions in accordance with information provided by the Government.

3.6.3 Program adaptation parameters.- Adaptation parameters to be added to the master program shall include but not be limited to the following major type categories of data, as based upon the requirements listed in this specification and supporting information to be provided by the Government.

- (a) Operating parameters of associated site equipment interconnecting to the sensor (e.g. radar system antenna rotation rate).
- (b) Sensor calibration data (e.g. monopulse/off-boresight tables).
- (c) Geographical data (e.g., site coverage map parameters).
- (d) Local terrain data (e.g., target reflection files).
- (e) Sensor calibration performance monitor parameters (e.g., location data of the Calibration Performance Monitoring Equipment (CPME) transponder equipment installations, sensor alarm decision tables, remote maintenance monitor data reporting criteria).
- (f) Sensor operational parameters to be used (e.g., transmitter power levels, ATCRBS mode interlace patterns).
- (g) Assignment of channels for surveillance and communication links to interconnecting user and support facilities.
- (h) Control of sensor logical functional elements, as to task assignments, normal on-line and redundant standby assignments, and selection of elements for off-line test activities when maintenance personnel are on-site.

- (i) Other sensor functional parameter values wherever specified as "site adaptable" in this document (parameters controlling sensor performance that may be affected by special conditions occurring at a particular site and hence requiring other than the nominal parameter value as listed, within the specified range).

3.6.4 Sensor site adaptation.- The site adaptation function shall provide the following capabilities, to be available for use by on-site maintenance personnel:

- (a) Installation of the master Mode S programs (as stored on a transportable nonvolatile mass storage media which may be required to be in Read Only Memory (ROM) format) in the sensor, accessible to the sensor program adaptation function.
- (b) Installation of the sensor site programs (as generated at the SSF/PSF facilities on a transportable nonvolatile mass storage media) in the sensor, accessible to the sensor program adaptation function.
- (c) Preparation of sensor site programs from either of the data sources specified in 3.6.4 (a) or (b), to be stored on a mass media accessible to the sensor startup function.
- (d) Selection of any of the sensor site adaptable parameters as stored in the sensor site program for modification of values by on-site maintenance personnel (either temporary or permanent changes).
- (e) Preparation of a sensor site program (duplicate copies for backup or documentation purposes) from either of the data sources specified in section 3.6.3c or d, to be stored on a transportable, nonvolatile mass storage media.
- (f) The site adaptation functions specified above shall be performed with minimum sensor down time (only the time required to load the new program data generated) and any peripherals required for performing these functions shall be special test equipment items brought to the site by maintenance personnel. The initiation and control of the site adaptation function shall be performed via any one of the RS-449 data input interfaces to the sensor as specified in sections 3.4.10.3 and 3.4.10.4 (remotely from RMMS or NAS facility or on-site).

3.7 Sensor architecture. - The sensor shall consist of two separate, identical channels capable of performing as specified herein. Each channel, and its component DPS and interrogator cabinets shall physically about the other channel in a universal manner, from any cabinets near corners, i.e. "L", "in-line", or back-to-back configurations. Each channel shall be capable of performing all the sensor functions while the other serves as a back-up in the event of a failure in the operating channel. The redundant channel shall maintain a copy of the operating channel's current data files. The architecture is shown in fig. 3.7-1.

The contractor shall provide all of the necessary switches, cables, control panels, junction boxes, dummy loads, and line terminations needed to interconnect each sensor channel into an operational dual channel sensor.

3.7.1 Sensor front end. - The following functions shall be implemented in each channel as special purpose hardware (including microprogrammable devices employing PROM's, ROM's, etc.):

- Transmitter/modulator (3.4.2)
- Multi-channel receiver (3.4.3)
- Mode S processor (3.4.4)
- ATCRBS processor (except reply correlation) (3.4.5)
- Performance monitoring hardware (3.4.10.2)
- Sensor timing (except the TOY clock which shall be separate from the front end) (3.4.13)
- Test target generator (3.4.14)

3.7.2 Computer subsystem. - The following functions shall be implemented in each channel as programs running on a computer subsystem:

- Channel management (3.4.1)
- ATCRBS reply correlation (3.4.5.6)
- Surveillance processing (3.4.6)
- Data link processing (3.4.7)
- Network management (3.4.8)
- Performance monitoring (3.4.10.3)
- Data extraction (3.8)

The ATCRBS reply correlation function shall be implemented as a single processor task. It is acceptable for this computer to be different from those used in the main computer complex if this is required to meet the ATCRBS capacity requirements.

3.7.2.1 General subsystem structure. - The computer subsystem shall consist of an appropriate set of one or more identical central processing units (CPU) that execute the programs implementing the sensor functions specified in 3.7.2. The sensor functions implemented as programs shall be partitioned as necessary such that identical CPUs may be used.

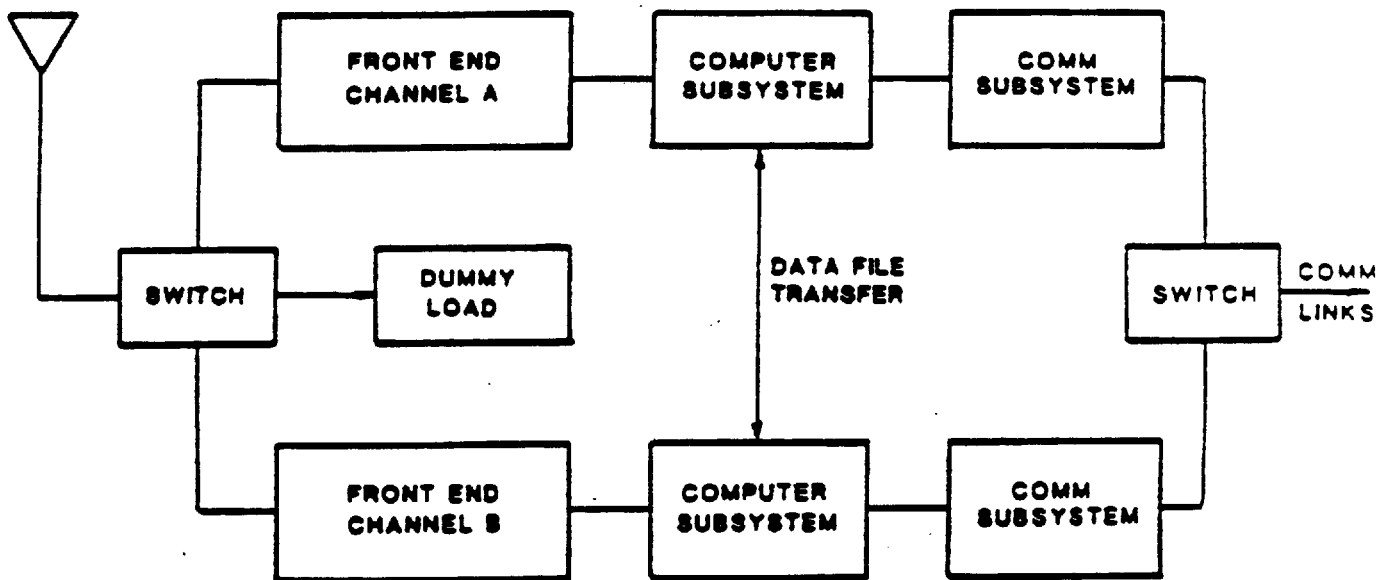


FIG. 3.7-1. MODE S SENSOR SYSTEM ARCHITECTURE

The read/write memories used by the processors shall be implemented using at most two types of memory components, one for memory used by a single processor and not accessible to other processors, and one for memory shared among processors.

The contractor shall maximize the uniformity of structure of the computer subsystem. All processors shall be able to access (1) all memories shared by more than one processor, and (2) all I/O device controllers. All data communication among processors shall be via such shared memories. All I/O device controllers that perform direct memory access transfer shall be able to access all shared memories and all direct memory I/O operations shall be performed using such shared memories.

(Uniformity of structure reduces design risk and enhances future flexibility by allowing functions to be moved from processor to processor without having to redesign the hardware configuration, or to reallocate data structures among memories).

3.7.2.2 Task assignment.- Each program running on the computer subsystem shall be assigned to a particular processor at the time the system is initialized. More than one program may be resident on a given processor. With the exception of communication tasks that interface directly with the communication subsystem, it shall be possible to take any program, including an I/O device control program, that runs on any processor of the computer subsystem, and run it successfully on any other processor in the subsystem without requiring modifications to the executable code or to the structure of the shared data or to the hardware. It is acceptable for minor changes to the contents of the shared data to be required (e.g., modified table contents) in order to accomplish this. It is also acceptable for minor changes in hardware control register contents to be required as long as these changes can be performed automatically under program control. The assignment of tasks to processors within the computer subsystem shall be made such that the reassignment of tasks has no impact on system performance.

3.7.2.3 Requirements.- Each processor unit and each memory unit must meet or exceed the following requirements:

- (a) Each central processing unit shall be a 16-bit or 32-bit device that contains all circuitry necessary to implement the instruction set. The use of special microcoded instruction sets in the control memories of individual CPU's is not precluded, provided that such microcode is identical in all processors or else can be loaded into any processor at system initialization time.
- (b) Each processor must have an addressing capability of at least 512K words.
- (c) Basic memory access time, exclusive of any bus access protocol, shall be 1 μ sec or less.

- (d) As a minimum, each memory shall be equipped with the capability to detect single bit errors.

3.7.2.3.1 Utilization.- The amount of memory provided shall be such that no memory is more than 60 percent utilized.

Programs shall be assigned to processors such that the total demand on each and every processor, averaged over a one second interval, shall not exceed 60 percent of the available computation time while under the worst case sensor load specified in 3.3.2.5.

3.7.2.3.2 Expansion.- The computer subsystem design shall allow augmentation of hardware to at least double processing power, triple memory, and triple the number and total data rate of input and output interfaces, beyond the processing power, memory, and input and output capacity needed to meet the overall capacity requirement of section 3.3.2.

3.7.2.4 Computer subsystem control.- Input/output (I/O) devices suitable for controlling the computer subsystem during system start-up, calibration and maintenance shall be provided (3.8.3.1). Specifically, these devices shall enable the:

- (a) Initial loading and start-up of the sensor, using a local, nonvolatile, non-mechanically actuated, storage medium.
- (b) Modification of sensor site parameters.
- (c) Initiation and control of diagnostic procedures.
- (d) Reassignment of tasks within the computer complex.
- (e) Switching of redundant elements from standby to operational status.
- (f) Recording on a local, non-volatile, non-mechanically actuated storage medium, of data describing significant events in the sensor's operation, such as status and configuration changes; and allow transmission of such data to a remote facility through the RMMS.

3.7.3. Calibration and performance monitoring equipment.- The calibration performance monitor equipment (CPME, Appendix VIII) is to be considered a part of the sensor for reliability determination. In particular, at least one CPME unit must be operating normally for the sensor to operate. The CPME subsystem must, therefore, use more than one identical but physically separate CPME unit, capable of being operated independently, at the same location or separate locations.

3.7.4 Communications subsystem.- The communications subsystem shall consist of the interfaces specified in 3.5.2 through 3.5.5, 3.5.7 and 3.5.10; and their associated control and switching systems.

Unless otherwise specified in the interface specification, the interface connection point is on the output of the communications subsystem switch. This switch (3.7) keeps each of the interfaces switched to the active channel unless otherwise specified.

3.7.5 Mode S sensor control.- The sensor shall provide automatic and manual control of sensor configurations. The following terms are used to describe the states of sensor components in the context of sensor control. A sensor component can be any system, group of subsystems, subsystem, etc., the term, component, as used here (3.7.5 and 3.7.6) is generic.

- (a) Active - in this state, the component is online and involved in Mode S startup, calibration, surveillance and datalink, or other Mode S functional activities (as opposed to certain implementation specific activities). One implementation specific activity could be setting the computer memories to a known state upon power up, there is no failure, but the equipment is not involved in Mode S functional activities and is therefore not active.
- (b) Standby - in this state, the component is online but not involved in Mode S active functional activities, however, the component is ready to become active, within a sensor or channel failure recovery time (3.9), as part of a sensor or channel failure recovery.
- (c) Recovering - in this state, the component is online and is part of a sensor or channel failure recovery that is expected to complete within the allowed sensor or channel failure recovery time, so that a sensor or channel failure is not expected to be declared.
- (d) Offline - in this state, the state of the component is any thing not in the above states. This includes any recovering component taking more than the allowed recovery time, and possibly resulting in a sensor failure. This recovery failure could result in having a components status change from recovering to offline. A component would normally be offline for maintenance that interferes with active component operation. Maintenance that interferes could be running repetitive built in tests that do not allow active component operation.
- (e) Online - this term applies to a component in active, standby or recovering states.

The sensor control hardware function shall be implemented twice, for redundancy, in the sensor control hardware of each sensor channel. The sensor design shall be such that failure of sensor components, other than any pair of redundant elements of the sensor control hardware, shall not inhibit the operation of the sensor control hardware function. The only exceptions are; failures that cause the complete removal of power from the sensor control hardware, and failures that prevent sensor control multi-point communications interface connection links from operating properly. If the sensor control hardware is connected to a multi-processor bus, this bus and its connected common-processor-memory elements and any input-output adapters for the use of sensor control may be considered a multi-point communications interface.

The sensor control hardware shall have interfaces to the computer, communications, and front end subsystems, and to the other sensor channel's sensor control hardware. As a minimum these interfaces shall be implemented with three independent connections as follows: (1) a computer and communications subsystem connection, (2) a front end connection, and (3) an other channel sensor control connection. The connection to the other sensor channel's computer and communications subsystems may be through the other sensor channel's sensor control function. The front end connection shall connect to all front end subsystems in the sensor, and shall be separate from the computer subsystem to front end connection, unless the computer subsystem to front end connection is the control path for sensor control. The sensor control hardware shall be part of the communications subsystem. The limits of the sensor control hardware shall be at the interface connectors of the interfacing sensor components and the sensor junction box.

The sensor shall have three independent manual control system interfaces (3.7.5.2) for sensor control. These interfaces shall be to the Remote control point (3.5.10 and 3.7.6.1), the Local control point (3.5.7.2 and 3.7.6.2), and the RMMS control point (MPS: 3.5.7.1).

The interface to the MPS (3.5.7.1) uses one communications connection, with separate link addresses for each sensor channel communications subsystem. Sensor control commands shall be accepted from only one link address at a time within a 10(10-240,10) second lockout interval. The sensor control functions in each channel shall coordinate this lockout, so that; 1) the loss of communications between the sensor control functions, or 2) the loss of one channel's sensor control function; shall allow each channel's surviving sensor control function to accept sensor control commands independently of the other channel. Any sensor control commands shall be accepted at a link address that is not locked-out, this includes commands that affect the other channel. Status display information shall be made available for each link address.

If the interface to the Local control point (3.5.7.2) uses two communication connections (one for each sensor channel communications subsystem), sensor control commands shall be accepted from only one connection at a time within a 10(10-240,10) second lockout interval. The sensor control functions in each channel shall coordinate this lockout, so that; 1) the loss of communications between the sensor control functions, or 2) the loss of one channel's sensor control function; shall allow each channel's surviving sensor control function to accept sensor control commands independently of the other channel. Any sensor control commands shall be accepted at a connection that is not locked-out; this includes commands that affect the other channel. Status display information shall be made available for each connection.

See 3.7.5.2 for manual sensor controls and status display.

3.7.5.1 Automatic controls.- The sensor shall provide the following automatic sensor controls, as a minimum. It is possible to disable these automatic controls (3.7.6). Some controls can be made inoperable. When an automatic control is made inoperable, the control shall not operate automatically regardless of whether the control is enabled or disabled.

- (a) Sensor channel switching; a channel failure in the active channel shall cause a channel switch, if there is a standby channel. In a back-to-back sensor, sensor channel switching shall always supply the front face antenna, over the back face antenna, with an available front end subsystem.

During ATCBI backup: 1) a channel shall be considered to be a front end subsystem, 2) in a back-to-back sensor, sensor channel switching shall only use the front face antenna, and 3) automatic channel switching is not required.

Sensor channel switching shall allow switching to uncalibrated channels, that are otherwise operational. When an uncalibrated channel is active it shall use the existing, uncalibrated, calibration table.

- (b) Selection of the active-online primary radar channel (3.5.2), for use by the sensor for data and control interchange with the primary radar.
- (c) ATCBI backup selection; for non ATCBI backup operation the sensor requires a minimum component set of a channel with; one front end subsystem, one computer subsystem and one communications subsystem; as well as one CPME, one APG and one TOY clock. When the sensor does not have this minimum component set that can become active within 10(5-240,5) seconds; or if the sensor has not had this minimum component set for the same period of time: the sensor shall switch to ATCBI backup mode (60.3.3).
- (d) ATCBI backup selection; when there have been no usable surveillance links (of the sensor's surveillance links), for the time specified in item (c) above, because of modem and phone line outages (this selection of ATCBI backup is not caused by Mode S equipment failure), the sensor shall switch to ATCBI backup mode. This provides the capability for analog backup.
- (e) Operation of the surveillance data selector (SDS); the SDS shall be operated as specified in 60.3.6. ATCBI backup mode shall be considered Mode S sensor failure for the operation of the SDS.
- (f) Return from ATCBI backup; when the conditions that cause automatic entrance to ATCBI backup mode do not exist, while in ATCBI backup mode, the sensor shall return to non-ATCBI backup operation. It shall be possible to make this automatic function of sensor control inoperable through site adaptation.

- (g) Selection of active APG; when the currently active APG has been declared failed by the sensor, the sensor shall select the other APG as active, if it is available as standby.
- (h) Selection of active TOY; a failure in the active TOY shall cause a selection of a new active TOY, if there is a standby TOY.
- (i) Selection of primary CPME; a failure in the primary CPME shall cause a selection of a new primary CPME, if there is another active CPME.
- (j) Automatic channel recalibration; when the performance monitor determines that unacceptable errors exist while using the calibration table of an uncalibrated active channel, and it is not possible for sensor channel switching to switch channels, azimuth calibration (as specified in 3.4.11.3) shall be initiated on the active channel prior to resuming normal operations.

3.7.5.2 Manual controls and status display.- The manual control and status display capabilities of the sensor manual control systems are specified in 3.7.6. The interface implementation for the Remote control point shall be documented in its own appendices of the required documentation.

The additional portion of each communications layer required to support the manual control and status display functions are specified below.

3.7.5.2.1 Manual control point application layer.- Not specified.

3.7.5.2.2 Manual control point presentation layer.- All messages shall be reasonably compact. Status messages shall be time stamped from the last sensor northmark TOY clock time, with minutes (of the hour) and seconds, as last reported by the sensor to sensor control.

3.7.5.2.3 Manual control point session layer.- Not specified.

3.7.5.2.4 Manual control point transport layer.- Not specified.

3.7.5.2.5 Manual control point network layer.- There shall be a two level control priority assigned to the three control and status display points. The following is the default:

Priority #1 -- Remote control point

Priority #2 -- Local control point
-- RMMS control point

Manual control of the sensor shall be allowed from only one of the three control points at any time (i.e., the priority #1 control point), however status shall be available for display at all control points. This status shall be updated once a scan or when it changes.

There shall be a procedure that allows a priority #2 control point operator to request priority #1 status; this change of control shall only occur if the current priority #1 control point operator concurs with granting the change. A priority #1 control point that concurs with a change of control becomes a priority #2 control point. A procedure shall allow the operator at a priority #1 control point, other than the Remote control point, to release control. The releasing control point shall become priority #2, and the Remote control point shall automatically return to priority #1.

These procedures shall be expanded to cover loss and reestablishment of capability (including lack of operator response) of the control points. As long as one control point remains operational and in communications with sensor control, manual control of the sensor shall still be possible. The single priority #1 control point requirement shall be maintained as control point capability changes.

All messages shall be sequence numbered with a sequence number that does not repeat within one scan.

The local control point and the RMMS control point are required to provide functions not specified as part of sensor control. However; these control points shall only be allowed to exercise any control functions (as opposed to requests for information) provided as part of these additional functions, when acting as the priority #1 control point.

3.7.6 Mode S manual control points.- The sensor shall have Remote control point equipment. This equipment shall provide the user interface for the display and control capabilities specified in 3.7.6.1. The RMS local terminal (3.5.7.2) shall host the control and display capabilities specified in 3.7.6.2, to provide the Local control point. The MPS interface (3.5.7.1) shall support the control and display capabilities specified in 3.7.6.2, to provide the RMMS control point.

3.7.6.1 Mode S remote control and status display point.- The sensor Remote control point shall provide its operator the following control and display capabilities. The manual controls shall cause the required action by the sensor whether the automatic controls are disabled or not. The use of a manual control, other than the disable or enable automatic controls, shall not change the enabled state of any automatic control. Controls not for the exclusive use of the priority #1 control point are indicated below.

- (a) Disable or enable the automatic controls of 3.7.5.1. Each alphabetical (in parentheses) item listed in 3.7.5.1 shall be individually controllable. There shall be a single command that can disable all automatic controls. There shall be a single command that can enable all automatic controls.

- (b) Select the active sensor channel (sensor channel switching). The non back-to-back sensor has two channel configurations to choose from. The back-to-back sensor has six channel configurations to choose from. Each back-to-back configuration has two front ends, however; it is possible one of these front ends is not installed, or one or more are failed. This function shall meet the same channel switch time duration as the automatic sensor channel switching function. The time from when sensor control is provided a manual command to the time that the sensor channel switch is started is allowed to be up to one second.

During ATCBI backup: 1) a channel shall be considered to be a front end subsystem, and 2) in a back-to-back sensor, sensor channel switching shall only use the front face antenna.

- (c) Select primary radar channel, for use by the sensor for data and control interchange with the primary radar.
- (d) Select ATCBI backup mode and return from ATCBI backup mode.
- (e) Select data source with the surveillance data selector (SDS) as specified in 60.3.6. The Remote control point, and RMMS control point shall be considered to be at the indicator site. The Local control point shall be considered to be at the local (Mode S) site.
- (f) Disable or enable Local control point.
- (g) Disable or enable RMMS control point.
- (h) Concur or non-concur with control transfer request from other control point.
- (i) Request control to be transferred to this control point (only available while acting as a priority #2 control point).
- (j) Display of control points status, including priority, state (online or offline) and whether the operator is responding or not.
- (k) Display of sensor status (as red, yellow or green), time of year of last sensor northmark, status of each channel configuration, status of TOY clocks, status of CPMEs, status of APGs, ATCBI backup selection, and SDS position.
- (l) Not used.
- (m) Display of disabled and enabled status of automatic sensor controls.
- (n) Display of primary radar interface status, including selected radar channel, and online or offline status of each channel.

When a control point is disabled it need not receive status display data, and a request control command shall not be accepted by sensor control from that control point.

3.7.6.1.1 Mode S remote control point operator interface.- The operator interface shall use a keyboard and CRT and shall be a terminal using the code for information interchange as specified in ANSI X3.4-1977, to provide the user interface specified below. The keyboard shall have a QWERTY alpha-numeric keypad, a cursor keypad, programmable function keys set horizontally with no other keys closer to the top of the keyboard, a numeric keypad, and other keys required to support the specified user input format (3.7.6.1.1.2). The CRT shall display 80 characters in a line and 24 to 25 lines on the screen. The data display rate to the CRT shall be at least 4800 bits per second.

3.7.6.1.1.1 Remote control point display format.- There shall be a part of the display reserved to indicate changes in status and to show the status of the sensor channels and the time of year of the last sensor northmark. There shall be a part of the display reserved to indicate the current control points priority and status, and to indicate change control (i.e. priority #1) requests.

The terminology for status display shall be as follows: Online shall be used for active and recovering, Standby shall be used for standby, and Offline shall be used for offline.

3.7.6.1.1.2 Remote control point user input format.- The selection of any one command shall not require more than nine keystrokes.

3.7.6.2 Mode S local and RMMS control and status display points.- The sensor Local control point shall provide its operator the capabilities of 3.7.6.1 and the following control and display capabilities. The local control point is not required to implement the user interface specified in 3.7.6.1.1. The sensor RMMS control point interface shall support the capabilities of 3.7.6.1 and the following control and display capabilities, however actual display formatting and operator interface will be provided by the MPS.

- (a) Select any sensor channel configuration to be standby or offline.
- (b) Select the online and offline states of any sensor component on the equipment cabinet level (control of equipment power not necessary).
- (c) Release control of the sensor. The Remote control point shall automatically regain control (i.e., the releaser becomes priority #2 and the Remote control point becomes priority #1).
- (d) Display of online and offline states of any sensor component on the equipment cabinet level.

- (e) Select any APG as active, standby for a given front end, or offline.
- (f) Select any TOY as active, standby for a given front end, or offline.
- (g) Select any CPME as active-primary, active-non-primary or offline.

A control point that disables itself shall be treated as if it had issued a release control command and then the Remote control point had issued a disable control point command.

3.7.7 Mode S/ASR-9 backup mode.- The Mode S contractor shall provide Mode S/ASR-9 Backup mode conversion kits if required by contract schedule. This kit shall include one surveillance link as specified in 3.5.3.3 with 3 modem connections. This kit shall include one surveillance data selector as specified in appendix VI (60.3.6). The ASR-9 is the collocated surveillance processor discussed in 60.3.6 for this application. The Mode S sensor shall declare collocated surveillance processor failure when both channels of the ASR-9 have been detected to have failed. Failure detection of the ASR-9 channels shall be as provided in the Mode S/ASR-9 interface as specified in 3.5.2.4. The expected operation of the SDS will be; operational mode two (60.3.6(b))

3.7.8 Mode S/ATC-BI back-up mode.- The Mode S contractor shall provide ATC-BI back-up mode conversion kits if required by contract schedule. The ATC-BI back-up mode is specified to provide beacon detection of aircraft. In ATC-BI back-up mode the Mode S front end is operated in manner identical to that of an ATCBI-5. The operation of transmitter and characteristics of output signals are specified in Appendix VI paragraph 60.3.3 through 60.3.3.1.5. The receiver is specified in 3.4.3.5 as auxiliary video output channel. In the ATC-BI back-up mode the sensor shall provide the capability in both channels to receive radar zero and pre-triggers from the on line radar channel. The Mode S sensor shall provide four quantized video outputs from the auxiliary video output channel (3.4.3.5) from the on line channel to be used by the ASR-9, CD-2, or ARTS-2A. The sensor shall provide the CD-2 and ASR-9 indication of its operation in the ATC-BI back-up mode.

3.7.9 Not used.-

This space intentionally unused.

-395-

3.8 Data extraction.- The sensor shall include a data extraction subsystem, capable of extracting data (3.8.1) from the operating system in real time, and recording that data for subsequent off-line reduction and analysis. The extraction process shall be selective prior to recording; that is, various categories of data (as specified in 3.8.1) shall be selectable for extraction while others are not. The extraction subsystem shall be capable of changing the particular set of data categories extracted in real time, under the control of an operator. The extraction process shall be "fail-soft;" that is, the process shall in no way encumber the capability of the remainder of the sensor system. As real-time demand on the sensor grows to the point where insufficient memory and/or capacity is available for full-sensor processing, appropriate indication shall be provided in the extraction data, and the extraction process shall be automatically reduced in extent. As demand on the sensor diminishes, the extraction process shall resume automatically. All sensors shall have the capability to extract all data in any one of the individual categories defined in 3.8.1, items (a) through (e), and in paragraphs 3.8.1.1 through 3.8.1.7 while at any load up to 50% of the capacity load defined in 3.3.2.5 through 3.3.2.5.3. The data extraction function shall also have the capability, through use of add on hardware or software if necessary, to extract all data in any one of the individual categories defined in 3.8.1, items (a) through (e), and in paragraphs 3.8.1.1 through 3.8.1.7 while at any load up to 100% of the capacity load defined in 3.3.2.5 through 3.3.2.5.3. If additional hardware or software is required to accomplish the full capacity extraction function, that hardware/software shall be in the form of a sensor modification kit, the number of which is defined in the contract schedule. The contractor shall provide, as a minimum, a complete listing of the various extraction messages, their formats, and proposed data reduction processing. Each type of extraction message shall be identifiable by a unique message code, to facilitate off-line data analysis.

It is acceptable for data to be collected in real-time under a generalized format and converted off-line to the formats specified.

3.8.1 Data categories.- The extracted data shall be categorized and placed on the recording media or transmitted to the support facility (3.5.5) as blocks of data. Each block shall contain only one category of data and shall have at the start of the block a unique tag to identify the data category within. The block shall be fixed for each category and the number of unique categories available shall be in excess of 1000.

The extraction process shall make available to the operator the option of creating new data extraction block categories. The block length, category tag and data to be extracted shall be selectable by the operator. A minimum of 50% of the possible category types shall be left unused by the contractor for this purpose.

The categories to be extracted shall be selectable. The operator shall have the option of deleting or adding category types after extraction has started without affecting the ones in progress.

Categories shall have site adaptable priorities associated with them in order to retain important data during periods of heavy data load when system limits cause data to be lost. There shall be at least four levels of priority. When

the condition exists that all requested data cannot be extracted and recorded, the lower priorities shall not be extracted. When these conditions clear, the lower priorities shall automatically be resumed.

The categories described below and in sections 3.8.1.1 through 3.8.1.7 shall be implemented by the contractor.

- (a) Interrogation and reply data, Mode S and ATCRBS target reports.
- (b) Radar reports, Mode S and ATCRBS target reports and surveillance file data.
- (c) Radar weather reports, radar reports, Mode S and ATCRBS target reports, and intersite surveillance dissemination data (surveillance link output or Mode S output to ASR-9).
- (d) Interrogation and reply data, Mode S target reports and all intersite communication link data.
- (e) Performance Monitoring data, scan data, and system diagnostics data. #

This space intentionally unused.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-4

-395b-

This page intentionally unused

- 3.8.1.1 Interrogation and reply data.- These data categories shall contain the total content of the interrogations created by channel management and the reply reports output by the reply processors. In addition all Mode S target reports and ATCRBS target reports shall be extracted. A unique category shall be assigned to each type of interrogation, reply, and target report. Each interrogation and reply shall have as part of its extraction block the value of the station time clock at the time of transmission or reception.

Filtering of the data to be extracted shall be available. The filtering parameters shall include range, azimuth, ATCRBS reply codes, Mode S interrogation and reply addresses, and scan number. The range and azimuth filters shall allow a minimum of three regions to be selected. The code and address filters shall allow a minimum of 50 ATCRBS codes and 50 Mode S addresses to be selected.

3.8.1.2 Surveillance data.- These data categories shall contain the total surveillance file data maintained by surveillance processing for each target. There shall be one target's track data per data extraction block and a unique category for each track type. The same filtering criteria as described in section 3.8.1.1 shall apply to track data extraction blocks. Extraction of a target's surveillance file shall be initiated when the file is updated by any process.

3.8.1.3 Performance monitoring data.- All parameters monitored by the performance monitoring function shall be available for extraction. The category types used for this data shall be selected such that each category contains parameters from no more than one subsystem.

Data shall be extracted at specified time intervals (1(1-60, 1) min) or upon a status change of one or more parameters. The parameters which initiate the extraction shall be selected by the operator.

- 3.8.1.4 Intersite data.- All surveillance and communications data leaving or entering the Mode S sensor shall be available for extraction. The time of year clock value at the time of reception or transmission shall be included as part of the data for each message. Data types included in these categories shall be surveillance dissemination data, communications data, radar input data and RMS data.

- 3.8.1.5 Scan data.- This category shall include scan number, number and type of targets being processed, time of year clock, station time clock and any other scan related data. Data shall be extracted at the time of north mark transition each scan. Provisions for time correlation of station time clock and time of year clock shall be provided to overcome any extraction timing problems.

3.8.1.6 System diagnostic data.- These data categories shall be for trouble shooting the sensor operation. Buffers, pointers, status registers and other data useful in isolating faults should be included. Since the system implementation will affect diagnostic processes, the contractor shall identify the data to be included along with methods for detecting and isolating faults.

3.8.1.7 Conditions of extraction. - The category shall contain the data extraction conditions which were selected. Categories selected, filters, site identifier, device(s) used, and any other data relevant to the conditions under which the extraction was made. This shall be extracted at 1(1-60,1) minutes intervals or when an extraction condition changes.

3.8.2 Data reduction. - Data reduction software shall be provided to process the extracted data. It shall be compatible with on-site equipment and with centralized data reduction facilities. This software shall provide the ability to view or obtain printed listings of all or selected types of extracted data and shall provide at least the following functions.

3.8.2.1 Quick-look data processing. - The operator shall have the capability to filter the data that will be viewed or printed via a keyboard entry device. Category type, scan number, time, ATCRBS code, Mode S address, track number, range, azimuth, and altitude shall be included as filter parameters. The filter parameters, when two or more are used, shall be grouped into logical expressions using "and" and "or" logic functions. The logical output of the filter expression shall determine which data is viewed or printed. There shall be the capability of having multiple filter expressions, each being independent and producing a particular type of data output.

The data output shall be in a form which is easily understandable. It shall be labeled with respect to type and units of the data. The labels shall be present at least once per page and be composed of text, abbreviations or acronyms.

3.8.2.2 Extended data processing. - Software shall be delivered to accomplish extended data processing of the extraction recordings (3.8.1). The extended data processing programs may operate on a Honeywell Series 66/60 computer (GCOS-3 operating system) or on the programming support facility (APPENDIX II, 20.2.1).

Extended data processing shall include all capability under 3.8.2.1 above and, in addition, shall provide, under parameter control, the ability to merge data from three Mode S sensors. The programs shall prepare listings, plots, graphs, and simulated plan position displays annotated with correlating time, position, identity, and data-link messages. Data provided as a result of extended analysis shall be plotted, graphed, and etc., with a minimum capability of 4K by 4K dot resolution and a hard copy shall be provided of at least 8.5 inches by 11 inches. All sensor-to-sensor messages, as well as sensor-to-ATC facility and sensor-to-non-ATC messages shall be included.

3.8.3 Extraction equipment. - The extraction equipment, except operator terminals, recording devices and printers, shall be kept on site. The equipment that is not kept on site shall be transportable, have an installation time of 30 minutes or less, and be manageable by one person.

The extraction function shall be controlled either remotely or by an on-site operator. During remote operation, no on-site recording or printing will be

required. A buffer of 16K words minimum shall be used to allow for short term data loads which exceed the telephone line limit.

3.8.3.1 Computer subsystem control and data extraction peripheral equipment. - The following I/O devices are typical of those which will be provided by the Government for operating the Data Extraction function. They will have I/O controllers compatible with the I/O system of the sensor's processor. Computer programs (3.12) shall include all necessary peripheral driver software.

- (a) Video display with keyboard; quantity 1
 - 150 character/second I/O rate, minimum
 - 72 characters/line, minimum
 - Character code compatible with that used by the processor(s) provided
 - Full duplex operation provided by both the device and its controller
- (b) Magnetic tape unit; quantity 2
 - 1/2 inch tape, 9 track, 1600 BPI, transfer rate at least 60,000 bytes per second, 2400 foot reel, FIPS-compatible format
 - The magnetic tape format shall conform to FIPS PUB 25.
- (c) Line printer; quantity 1, interfaced to Video display (3.8.3.1(a))
 - 120 columns/line, minimum
 - 480 lines/minute, minimum

3.8.4 Sensor programming support facility. - Equipment and software necessary to modify computer programs, compile system programs with various site adaptations (3.6), perform software debugging, and do quick-look processing of recorded data (3.8.2.1) will be provided. In addition, the programming support facility may provide extended data processing (3.8.2.2). The capability for accomplishing these functions is specified in Appendix II.

This space intentionally unused.

3.9 Reliability and maintainability.- The equipment specified herein shall comply with the reliability and maintainability requirements as specified in the following subparagraphs. The Mode S sensor's reliability shall be such that, in conjunction with compliance of the maintainability requirements, the Mode S sensor availability requirements are met.

3.9.1 Definitions applicable to reliability and maintainability.- The following terms have specific meanings in the context of reliability and maintainability.

- (a) Sensor - All equipment required to satisfy all requirements in this specification. The maximum complement of hardware and software required at any single site shall be the configuration used for reliability and maintainability purposes.
- (b) Sensor Availability - Sensor availability is the probability of the sensor operating as specified at any instant in time over the service life of the sensor. Sensor availability (intrinsic), A, shall be calculated as follows:

$$A = \frac{\text{Sensor MTBF}}{\text{Sensor MTBF} + \text{MTTR}}$$

- (c) Sensor Failure - Sensor failure can be the partial or complete loss of a sensor function or capability. Interruptions in normal sensor operation of less than 100 msec due to the failure of a sensor element for which redundancy exists shall not be counted as a sensor failure.
- (d) Nonrelevant Failures - At the discretion of the Government monitor, failures that result from the following factors may be recorded as non-relevant failures:
 - (1) Failures in commercial power, or other external equipment.
 - (2) Negligence of operating or maintenance personnel.
- (e) Relevant Failures - All failures are relevant until demonstrated by the contractor to be nonrelevant to the satisfaction of the Government.
- (f) Sensor Mean-Time Between Failure (MTBF) - The average time between sensor failures.
- (g) Mean-Time Between Channel Failure (MTBCF) - The average time between channel failure.
- (h) Failure - Failure is the inability of any part, assembly, or subassembly to perform the functions for which it was designed with its specified design limits.

- (i) Lowest Replaceable Unit (LRU) - An LRU is a unit (component, element, module, etc.), that must be replaced to restore a failed system or system function.
- (j) Mean-Time to Restore (MTTRS) - The average time associated with the restoration of the system functional capabilities.
- (k) Mean Bench Repair Time (MBRT) - MBRT is the average length of time to repair an LRU. This time includes failed component isolation time, component replacement time, and time required to verify the LRU is operational.
- (l) Mean-Time to Repair (MTR) - The average time associated with the site repair of the sensor by replacement of a LRU. This includes the time to isolate the failed LRU, replace the LRU, and verify that the function involved is repaired.
- (m) Channel - A channel consists of one (1) front-end, one (1) computer subsystem, one (1) communication subsystem, two (2) CPMs, two (2) TOY clocks (considered as redundant), and all associated switches and auxiliary circuitry required to support the channel operation.
- (n) Channel Failure - The complete or partial loss of any function, excluding redundant elements within a channel, including all associated switches and auxiliary circuitry required to support the channel operation.

3.9.1.1 Maintenance Concept.- High availability of the sensor shall be achieved by a combination of original equipment selection and design for reliability, and maintainability coupled with maintenance procedures designed to isolate and repair/replace elements quickly.

The general approach to maintenance is to monitor Mode S sensors remotely at a central location. When a failure occurs, alarms will alert maintenance personnel who can diagnose the problem to the LRU level using remotely initiated and remotely monitored system diagnostics.

Upon isolation of the faulty LRU(s), personnel will be dispatched to the sensor site to replace the faulty unit(s) and initiate system verification. Complete system checkout and normal preventative maintenance tasks will be accomplished prior to leaving the sensor site.

Failed LRU(s) will be returned to a central maintenance center where bench repairs will be performed and the repaired LRUs will be verified.

The design and operational characteristics of the maintenance concept are further described in FAA Order 6000.10.

3.9.2 Sensor reliability and maintainability requirements.- The Mode S sensor, including expansion provisions (3.7.2.3.2), shall achieve the following reliability and maintainability requirements:

3.9.2.1 Reliability.-

- (a) The sensor shall automatically protect each major component, module, and subsystem, from failures induced by improper operation or failure of any other sensor component, module or subsystem, or any external device connected to the sensor or communicating with it.
- (b) Hardware error detection circuitry shall be implemented in processors, memories and their interconnections such that the estimated mean time between undetected errors within the computer subsystem is greater than 20,000 hours. The integrity of surveillance and communications messages sent between the computer subsystem and the communications subsystem ground link format generating functions (e.g., ADCCP, CD) shall be protected by byte parity encoding or better. #
- (c) The error detection and recovery procedures shall be such that erroneous data produced directly or indirectly as a result of detected errors shall not be entered into the sensor data base nor leave the computer subsystem.
- (d) The primary copy of the system's program instructions and constant data resident in memory shall be protected from being accidentally overwritten. If normal system operation or recovery procedures require the copying of such data, all such copies shall be checked against the original by direct comparison or by other equally effective means.
- (e) The sensor design shall permit detailed fault diagnosis, on-site repair or replacement of any of its parts, and verification of proper operation of the repaired channel, without degradation or disruption of the sensor's normal service.
- (f) Recovery procedures shall be implemented such that any detected failure results in the reconfiguration of the system as necessary to achieve correct operation at full capacity. Recovery procedures shall be such as to preserve critical surveillance track and any other critical information which cannot be reproduced by normal sensor operation within the recovery time. (This shall be true even in the case of memory failures). The maximum time to complete such reconfiguration shall be 100 milliseconds. The reconfiguration time shall be measured from the time of error detection to the time that known good data is available at the output port(s).
- (g) Failure detection shall be performed on both channels regardless of their state, i.e. active or backup. Where redundant components are used within a channel, failure detection shall be implemented for these components. In the case of failure of a redundant component within a channel the recovery action required is to make that component unavailable within 100 milliseconds and to restore the standby capability of the channel within 2 minutes.

- (h) The sensor shall allow switching of input and output interfaces to accommodate the use of redundant elements in related external systems.
- (i) Notification of the failure of any element shall be available at the RMS output within 1.0 second from the time the error is detected.
- (j) Data in memories shared among processors shall be preserved over power failures of up to 4 hours duration. It is not required that reading or writing of data be supported during power failures, however. The system shall automatically recover from such failures.
- (k) Mode S sensor availability as defined in 3.9.1 shall equal or exceed 0.99995.
- (l) The design, including definition of units of backup, shall be such as to preclude dependent failures among units.
- (m) The sensor shall recover its full operational capability automatically following power restoration after an external power interrupt. If the duration of the power interrupt is less than 15 seconds, all sensor files shall be preserved and recovery shall be effected within 15 seconds. If the duration of the power interrupt is between 15 seconds and four hours, all sensor programs, adaptation parameters, and constants shall be preserved, but files pertaining to tracks, data-link messages, tasks in progress and other items related to real time shall be purged during restart; recovery of the sensor shall occur within 15 seconds if the ambient temperature is between 30°C and 50°C. If power failure occurs for longer than 4 hours, recovery shall take place in less than one-minute if the ambient temperature is greater than or equal to 30°C. If the ambient temperature is less than 30°C, additional recovery time is permissible up to a maximum of 15 minutes at -10°C. The recovery time increases linearly from 0 minutes at 30°C to 15 minutes at -10°C. In any case, no damage shall occur to the sensor as a result of the power failure.
- (n) The sensor MTBF as defined in 3.9.1 shall be 20,000 hours.
- (o) The MTBCF (θ_0) shall not be less than 1,100 hours ($\theta_1 = \theta_0/2$).
- (p) The service life of a Mode S sensor shall be 20 years, minimum.

3.9.2.2 Maintainability.

- (a) Scheduled maintenance (i.e., preventative maintenance) shall be required no more frequently than once within each 91 day period.
- (b) The scheduled maintenance shall require no more than four hours.
- (c) Corrective Maintenance (unscheduled): The repair or replacement of redundant elements shall not interrupt normal sensor operation.

- (d) The MTTR for a sensor channel shall not exceed 1.0 hour, and 90 percent of all repairs shall not exceed 2 hours, to include all failures in the channel. Any single LRU failure shall be isolated, the LRU replaced, and the correct operation of the channel verified in an average time of 15 minutes, and 90 percent of single LRU failures within 1.0 hour.

3.9.2.3 Exclusions from 3.9.2.1 and 3.9.2.2.-

3.9.2.3.1 Sensor programming support facility.- The sensor programming support facility (3.8.4) in its entirety is excluded from the requirements Sections of 3.9.2.1 and 3.9.2.2. The requirement for the SPSF shall be (a) reliability exceeding 3000 hours MTBF, (b) maintainability less than 0.5 hours MTTR.

3.9.2.3.2 Auxiliary video output channel.- The auxiliary video output channel (3.4.3.5) shall meet the applicable requirements of 3.9.2.1 and 3.9.2.2, but shall not be part of the system reliability model.

3.9.3 Reliability program.- The contractor shall establish and maintain an effective reliability program in accordance with 4.1, 4.2, and 4.4 of MIL-STD-785. The reliability program shall be planned, integrated, and executed in conjunction with other design, development, production and testing functions with consideration for total system life cycle cost. The reliability program shall include the management and technical resources, plans, procedures, schedule, and controls for the work necessary to assure achievement of the reliability requirements.

3.9.3.1 Reliability program plan.- The contractor shall provide a reliability program plan in accordance with Task 101 of MIL-STD-785. The reliability plan shall be submitted to the Government for approval, and when approved, shall become the basis for contractual compliance.

3.9.3.2 Control of subcontractors and suppliers.- The contractor shall assure that his subcontractors' and suppliers' reliability efforts are consistent with overall system requirements, and shall monitor and control their reliability activities in accordance with Task 102 of MIL-STD-785.

3.9.3.3 Reliability program tasks.- The reliability program shall include the following tasks as described in MIL-STD-785, and shall be executed in accordance with the requirements and guidance provided therein.

- (a) Task 101 - Reliability Program Plan
- (b) Task 102 - Monitor/control of subcontractors and suppliers
- (c) Task 103 - Program Reviews
- (d) Task 104 - Failure Reporting, Analysis, and Corrective Action Systems
- (e) Task 201 - Reliability Modeling
- (f) Task 202 - Reliability Allocations
- (g) Task 203 - Reliability Predictions
- (h) Task 204 - Failure Modes, Effects, and Criticality Analysis
- (i) Task 205 - Sneak Circuit Analysis

- (j) Task 206 - Electronic Parts/Circuits Tolerance Analysis
- (k) Task 207 - Parts Program
- (m) Task 208 - Reliability Critical Items
- (n) Task 209 - Effects of Functional Testing, Storage, Handling, Packaging, Transportation, and Maintenance
- (p) Task 303 - Reliability Qualification Test Program
- (q) Task 304 - Production Reliability Acceptance Test Program

Additional requirements are stated in the following paragraphs.

3.9.3.3.1 Design techniques.- The Mode S sensor and its supporting equipment shall be designed such that each part and component is operated well within its design ratings. The parts shall not be subjected to conditions during operation, transit, or storage which exceed the values obtained when the device's maximum ratings have been reduced (derated) as required by this paragraph or 3.11.2.12, whichever is more restrictive. No part shall operate at more than that specified in the FAA Approved Reliability Design Techniques in its voltage-temperature and power dissipation-temperature stress ratings. The operating temperature for temperature-constrained parts shall be at least 10°C below the device's maximum operating temperature. The operating temperatures used for these ratings shall be +50°C plus the appropriate internal temperature rise when the devices are operated in the equipment with its doors closed, or +30°C plus the internal temperature rise with the doors open and parts extended for accessibility, whichever is greater.

A parts control program shall be established using MIL-STD-965, Procedure I, as guidance.

3.9.3.3.2 Thermal design analysis.- The contractor shall analyze the thermal design of all Mode S equipment. The analyses shall provide the necessary means to assure that the design and all parts, components, and materials meet the requirements of 3.11.1.2.1, 3.11.2.4, and 3.9.3.3.1 herein.

An analysis of each power supply shall be accomplished. These analyses shall consider all electronic parts and current carrying hardware (lugs, bolts, cables, etc.), including insulating and other materials used with or within one inch (2.54 cm) of these components. Each circuit card assembly and plug-in module shall be diagnosed to determine typical power dissipation per assembly and major current carriers and dissipators on the assembly. For digital logic cards and similar assemblies estimated power dissipation per board shall be provided.

The analyses shall estimate temperature rise of cooling air passing through each power supply, each module and through the entire Mode S sensor. Where it is determined that local areas of elevated temperatures exist, these areas shall be investigated and any design changes necessary to bring the conditions within these requirements shall be implemented. The results of these analyses shall be provided as specified in 3.13.2.1.2.

3.9.3.3.3 Reliability analysis.- The contractor shall analyze the over-all reliability of the Mode S sensor and its supporting equipment. The analysis shall be a part of, and have influence in, the program management and

equipment design tasks such that an optimum balance between life cycle cost, performance, and schedule is obtained within the requirements of this specification. The sensor's reliability requirements (3.9.2.1) shall be apportioned to lower levels within the system by allocating reliability goals to each module, equipment, assembly, and subassembly which is designed by the contractor or purchased as an entity from a subcontractor or supplier. The allocation shall be based on the system reliability model, the system reliability performance requirements, and on life cycle cost, schedule, and state of the art. The initial allocations shall be refined as the design progresses.

3.9.3.3.4 Reliability predictions.- A reliability prediction (sensor MTBF) shall be made for each type/capacity of the Mode S sensor equipment. The predictions shall be provided as specified in 3.13.2.1.2. All reliability predictions provided shall be based on a ground-fixed environment at component ambient temperatures as estimated in the thermal design analysis. Each prediction shall be based on the proposed design and the reliability model of the system elements, and shall meet the requirement of MIL-STD-756 for a Type III prediction. MIL-HDBK-217 shall be used as the source of failure rate data for electronic parts. The Rome Air Development Center's (RADC) Technical Report, TR-75-22, RADC non-electronic reliability notebook, section 2, shall be used as the source for failure rates of nonelectronic parts. Other failure rate data which is not in accordance with these requirements may be used; however, each such use shall be individually justified by the contractor and shall be permitted only upon Governmental approval. In all cases, the failure rates utilized shall reflect the measured or calculated stresses on the components in their environment within the equipment (3.9.3.3.1).

3.9.3.3.5 Total logistic predictions.- The contractor shall make a total logistic failure rate prediction, MTBF, for each of the conditions requiring a reliability prediction (3.9.3.3.4). The logistic prediction shall be similar to the reliability prediction, but it shall include all failures, not just those which can cause outages. The logistic prediction shall reflect failure rates of all equipments and hardware in the Mode S system. It will be used to produce a measure of the maintenance and logistic workload necessary to maintain the sensor in its operational state. It shall be prepared as specified in 3.13.2.1.2.

3.9.3.3.6 Failure modes, effects, and criticality analysis.- The contractor shall incorporate a failure modes, effects, and criticality analysis into the design process at its inception and continually update the analysis as the design evolves. The analysis shall include all functional requirements of the Mode S sensor and its supporting equipment down to the level of repair contemplated for complete maintenance of the equipment. The applicable modes of failure for each replaceable element shall be injected into the analysis to ascertain critical areas based on the functions performed and the expected failure rates. The results of the analysis shall be used by the contractor to evaluate the reliability model, detect critical areas and, if necessary,

implement design changes. Items which are critical to the reliable operation of the sensor shall be identified and handled as required by Task 208 of MIL-STD-785. Particular attention shall be paid to redundant applications to insure that the redundancy is not invalidated by obscure circuit effects or sneak paths. The contractor's reliability engineers shall work with the hardware and software design engineers on a continuing basis to accomplish at least the following:

- (a) Identification of system, subsystem, and component failure modes
- (b) Identification of probable causes of failure
- (c) Identification of failure symptoms
- (d) Identification of the effects of failures on the system operation and functions
- (e) Determination of failure rates
- (f) Recommendation of appropriate corrective features such as redundant elements, failsafe or failsoft designs, and selection of more reliable parts
- (g) Assistance in the formulation of test criteria to be used, in light of the identified critical failure modes

The results of the analysis shall be provided as specified in 3.13.2.1.2.

3.9.3.3.7 Effects of storage and handling.- The effects on reliability of functional testing, storage (including shelf life), packaging, transportation, handling, and maintenance actions shall be assessed and incorporated into the reliability program in accordance with Task 209 of MIL-STD-785.

3.9.3.3.8 Design reviews.- The contractor shall be prepared to explain and fully discuss its reliability program at the Mode S sensor design reviews as established by the contract schedule. The reliability portion of the design reviews shall be conducted in accordance with Task 103 of MIL-STD-785.

3.9.3.3.9 Failure reporting, analysis, and correction.- The contractor shall establish a closed-loop procedure for the reporting and correction of failures in Mode S sensor equipment both in the factory and at the site. The reporting shall be accomplished in accordance with Task 104 of MIL-STD-785, except where deviations are fully justified in the approved reliability program plan. As a minimum, all failures occurring after the time that the individual equipment's design is frozen and before the final acceptance of each Mode S sensor and each piece of supporting equipment shall be reported and corrected. The contractor shall statistically analyze all reported failures to determine system weak links and failure trends. All failures shall be analyzed to determine cause of failure and mode of failure. Failure data reports to the component level that include the results of individual and trend analyses shall be maintained in a centralized file to which the Government has unlimited access. Summaries of failures shall be prepared and shall include the identification of each failure, the results of each failure analysis, the equipment failure mode and symptoms, the cause of the failure and any corrective action taken, planned or recommended. The status of the corrective action and a statement as to the failure's relevance to any test (maintainability, reliability or similar tests)

as well as a description of any discernible trends or patterns shall also be included. The failure summaries shall be included in the final test reports (3.13.1.5).

The prime contractor shall also establish a similar procedure for reporting of all failures in all deliverable subcontractor items. This reporting procedure shall commence with the first application of power to the unit. All failure reports of subcontractor items shall be traceable to the Mode S equipment in which the item is to be used.

3.9.3.3.10 Reliability status.- The contractor shall prepare and submit quarterly reliability status reports in accordance with Task 103 of MIL-STD-785. Each status report shall state the status of each task enumerated in the reliability program plan and explain the schedule impact of any differences between the program schedule and the progress reported. Problems, trends, and contractor's resolutions to problems shall be discussed as they relate to each task. The status of all corrective actions shall be reported.

3.9.4 Maintainability program.- The contractor shall establish and maintain a Maintainability Program in accordance with the approved Maintainability Program Plan to assure the maintainability requirements of this specification are met.

3.9.4.1 Maintainability program plan.- The contractor shall prepare a maintainability program plan which conforms to the requirements of MIL-STD-470.

3.9.4.2 Not used.

3.9.4.3 Maintainability program tasks.- In addition to the requirement of MIL-STD-470 the following requirements also apply.

3.9.4.3.1 Maintainability analysis.- The contractor shall analyze the maintainability of the Mode S sensor and its supporting equipment in accordance with paragraph 5.2 of MIL-STD-470. The analysis shall be consistent with the reliability and maintainability requirements herein and the concepts described in the maintainability program plan.

3.9.4.3.2 Maintenance plan inputs.- The contractor shall prepare the inputs specifically included in paragraph 5.3 of MIL-STD-470. These inputs shall be updated should any design or production changes impact the validity of the previously supplied inputs.

3.9.4.3.3 Maintainability design criteria.- The contractor shall establish, apply, and update as necessary maintainability design criteria in accordance with paragraph 5.4 of MIL-STD-470 as supplemented herein. Components requiring

little or no preventive maintenance shall be utilized where possible. Each operational and diagnostic self-test shall be designed to have a failure rate equal to or less than ten percent of that of the equipment or module being monitored. The self-test functions shall be at least 95 percent effective in detecting and identifying functional failures in their respective modules and functional loops within those modules. The fault isolation function of the system diagnostics shall be at least 95 percent effective in isolating a single detected fault to one LRU. The false indication rate of each self-test function shall be equal to or less than five percent. The contractor shall demonstrate that the effectiveness of the self-test functions and the false indication rate meet the requirements stated above, with a confidence of 90 percent.

3.9.4.3.4 Not used.

3.9.4.3.5 Maintainability predictions.- The contractor shall make maintainability predictions and establish the appropriate preventive maintenance requirements in accordance with paragraph 5.6 of MIL-STD-470. Preliminary predictions of mean corrective and preventive maintenance times shall be provided as specified in 3.13.2.1.3. These predictions shall be updated and refined during the design and development stages. An early design prediction shall be prepared in accordance with Procedure III of MIL-HDBK-472 and a final design prediction shall be prepared in accordance with Procedure II, Part B of the same handbook. The procedures, accomplishment times, and schedules of each of the recommended or established preventive maintenance tasks shall be included in the early and final design predictions. The early and final design predictions shall be provided as specified in 3.13.2.1.5.

3.9.4.3.6 Design reviews.- The contractor shall be prepared to explain and fully discuss its maintainability program at the Mode S sensor design reviews as established by the contract schedule. The maintainability portion of the design reviews shall include, at a minimum, information of the type required by paragraph 5.9 of MIL-STD-470, and the following:

- (a) Current maintainability estimates and achievements as derived from predictions or tests
- (b) Status of each task in the maintainability program plan
- (c) Results of the design tradeoff studies
- (d) Effects of engineering and management decisions and changes upon maintainability achievements, trends, and potentials
- (e) Status of subcontractor and supplier maintainability programs
- (f) Functioning of maintainability data collection systems
- (g) Review of problems and any unresolved issues

3.9.4.3.7 Maintainability data collection.- The contractor shall establish a data collection procedure for validating maintainability predictions and evaluating maintainability demonstrations. The procedure shall be established in accordance with the requirements of paragraph 5.10 of MIL-STD-470, with the phrase "Mode S sensor preliminary design review" being substituted for "contract definition" in two places.

3.9.4.3.8 Maintainability status.- The contractor shall prepare and submit maintainability status reports in accordance with paragraph 5.12 of MIL-STD-470.

Each status report shall state the status of each task enumerated in the maintainability program plan and explain the impact of any differences between the program schedule and the progress reported. Problems, trends, and contractor's resolutions to problems shall be discussed as they relate to each task. The status of all corrective actions shall be reported.

This space intentionally unused.

FAA-E-2716

-410-

This page intentionally unused.

3.10 Maintenance and test equipment.- The Mode S sensor and its supporting equipment shall be designed and constructed to minimize the need for additional standard off-the-shelf equipment, tools and fixtures for maintenance and adjustment of all elements.

Since all Mode S sensor maintenance test equipment (standard and specialized) will normally be available only at a central maintenance facility, to be transported as needed to any specific site, essential off-the-shelf items must be designed for this type of service. The time required to attach and set up this test equipment at the Mode S sensor shall be considered a part of the "mean time to repair" as specified in this document.

The contractor shall furnish to the Government a list of recommended maintenance equipment (standard and specialized) and related accessories necessary for the performance of the following type Mode S sensor (and its supporting equipment) maintenance functions:

(a) On site-functions:

- (1) Sensor control (e.g., control functions specified in sections 3.4.12 and 3.4.14).
- (2) Sensor support data storage/transfer peripherals (e.g., functions specified in sections 3.4.11, 3.4.12, 3.6, and 3.8).
- (3) Sensor diagnostic test peripherals as required for off-line functional testing (location and replacement of failed LRUs).
- (4) Sensor alignment equipment (off-line components, as required after LRU repair/replacement).

(b) Regional maintenance facility functions:

Testing and repair of LRU assemblies (e.g., location and replacement of failed subassembly discrete components).

(c) Central system maintenance facility functions:

Periodic rework/repair/alignment/testing of major system components (e.g., antenna systems, receiver, transmitters, ARIES).

3.10.1 Standard maintenance equipment.- Standard maintenance equipment is defined as the tools and test equipment that are a part of a manufacturer's standard product line and are available off-the-shelf. The contractor shall provide a list of recommended standard maintenance equipment and related accessories necessary for the maintenance functions specified above

(section 3.10). Multiple-source of production solid state units which meet the requirements of section 3.9.2.3 shall be designated where available.

All standard test equipment (off-the-shelf) that requires modification to perform the intended function shall be defined as special maintenance equipment (3.10.2) and shall be provided by the contractor as required by the contract schedule.

3.10.2 Mode S specialized support equipment.- The contractor shall provide specialized test equipment as required to perform the maintenance functions for the Mode S sensor and its associated elements wherever standard test equipment cannot be used, as approved by the Government, in a quantity as specified in the contract schedule. This equipment shall meet all applicable construction and performance requirements of this specification.

Maintenance equipment in this category shall include but not be limited to the following items.

3.10.2.1 Circuit card assembly test set.- The contractor shall provide a quantity of special automatic circuit card test equipment (GENRAD 2272) for depot use. The quantity of GENRAD units required shall be determined on the basis of all circuit card repair performed at one central depot, operating at 8 hours per day and 5 days per week with a repair cycle time compatible with the spares provisioning requirements specified in 3.14 to 3.14.3.

3.10.2.2 Plug-in assembly extenders.- The contractor shall provide appropriate extender devices that permit plug-in assemblies which are normally inaccessible, to be extended such that all parts and wiring are accessible to maintenance personnel and test equipment. The extenders shall be polarized to prevent incorrect insertion, but shall not be keyed in a manner which would preclude using extenders on all assemblies with the same connector type. Plug-in assemblies with voltages in excess of 150 volts or connector currents in excess of 5 amperes shall not require extension. The contractor shall provide sets of extender devices consisting of one of each type used in the sensor. The quantity of sets to be provided shall be as required by the contract schedule.

3.10.2.3 Special tools and ancillary items.- The contractor shall provide all of the special tools and ancillary items needed to support the installation, maintenance, and adjustment of the Mode S sensor and its supporting equipment.

3.10.2.4 Other equipment.- The contractor shall provide all other components identified as specialized test equipment elsewhere in this specification (e.g., TTC Manual Control Panel).

This space intentionally unused.

3.11 General design requirements.- The Mode S sensor shall be designed and constructed to comply with the electrical and mechanical design requirements specified in the following paragraphs. All modules and assemblies of a given type shall be identical and interchangeable. General design and construction of the equipment specified herein shall be in accordance with FAA-G-2100 and the maintenance concept of Appendix X.

3.11.1 Electrical design requirements.- The electrical design of the Mode S sensor, including ac supplies, electronic design, system grounding and electromagnetic interference shall be in accordance with the following requirements. The design shall minimize electrical power consumption as much as possible.

3.11.1.1 Operational electrical conditions.- The Mode S sensor and its supporting equipment shall be designed using the following design center values and shall meet all functional and performance requirements specified herein in accordance with FAA-G-2100, para. 3.3.2.4, when operating from a primary power source with the following service condition values:

<u>Source Parameter</u>	<u>Service Condition Range</u>
120V design center, single phase	102 to 138V
208V design center, three phase	177 to 239V
60Hz design center frequency	57 to 63 Hz

The Mode S sensor shall use three-phase, 4-wire wye power, and its supporting equipment shall use single-phase power.

3.11.1.1.1 Electrical transients.- The Mode S sensor shall not output false operational or maintenance signals as the result of turning on or off the off-line channel or any module in the on-line channel. The Mode S sensor and all supporting equipment shall meet all functional and performance requirements, and the Mode S sensor operational equipment shall not output any such false data during operation under the environmental conditions listed in FAA-G-2100, paragraph 3.3.2.5 as modified below:

- (a) Define "slowly varying ac line voltage" as changing at the rate of 5.0V/sec or less.
- (b) Define "slowly varying ac line frequency" as changing at the rate of 1.0 Hz/sec or less.
- (c) The Mode S sensor equipment shall operate correctly with no shutdown in the presence of partial or complete losses of the line voltage(s) for up to 20 milliseconds at a time. For partial or complete loss of voltage(s) for more than 20 milliseconds and less than 15 seconds, the Mode S sensor equipment may stop, but shall preserve all fields and

data and return to normal operation on the return of voltage(s). For partial or complete loss of voltages longer than 15 seconds, the sensor shall perform a startup per 3.4.12, herein.

3.11.1.1.2 Startup surges.- The peak inrush current demanded by any Mode S sensor configuration from the primary power source shall not exceed three times its normal peak operating current with all modules functioning. The duration of the inrush condition shall not exceed four seconds, as measured from application of power to the time at which the current reaches or falls below the peak operating value.

3.11.1.1.3 Power consumption.- The contractor shall specify the total power consumed by each Mode S sensor configuration as delivered to the Government. This consumption shall include all operational and maintenance equipment loads and exclude the convenience output loads. The equipment power factor shall not be less than 0.80.

3.11.1.1.4 Transient protection.- All equipment shall be protected to prevent damage from electrical transients as specified in FAA-STD-020.

3.11.1.1.5 Lighting protection.- All equipment shall be protected from the effects of lightning as specified in FAA Order 6950.19, Ch.2.

3.11.1.2 Operating environment.- The Mode S sensor and its supporting equipment shall meet all functional and performance requirements specified herein under the environmental conditions of FAA-G-2100, paragraph 3.2.15 for environment II, in continuous, unattended duty at altitudes from sea level to 10,000 feet (3000 m) above sea level. The standard design center value for ambient temperature shall be +30° Celsius (C).

However, the contractor may propose exceptions to this requirement, such as a combination of the highest temperature, humidity, and altitude requirement at one time, subject to approval of the Government. For any exceptions taken, the contractor shall provide the Government with appropriate evaluation data to support the proposed exception.

3.11.1.2.1 Operating in extremes of climate.- The equipment shall be designed for continuous operation within the environmental conditions specified in 3.11.1.2. The contractor shall provide information in the equipment's instruction book as to what measures must be taken to operate the equipment under extreme conditions (outside of those in 3.11.1.2) which may be encountered in any area of the United States or its possessions. This requirement is not subject to verification by testing, but directs attention to the design, quality of materials, and workmanship required.

3.11.1.3 Nonoperating environment.- The Mode S sensor and its supporting equipment shall meet all functional and performance requirements specified herein when returned to the conditions of 3.11.1.1 and 3.11.1.2 after exposure to the following conditions:

- (a) Ambient temperature -55° to +65° C
- (b) Altitude 2,000 feet (600 m) below, to
15,000 feet (4,600 m) above
mean sea level

3.11.1.4 Input AC line controls.- Except as otherwise permitted each Mode S sensor module shall have its own power supplies and associated controls for the input ac power lines. In addition, a master power control for each Mode S sensor cabinet and an overall sensor main power control shall be provided. All controls shall meet the requirements of FAA-G-2100 paragraph 3.3.2.1. The power on-off controls for each module shall be circuit breakers meeting the requirements of 3.3.2.1.5 of FAA-G-2100; fuses shall not be allowed as protective devices for any module. A tripped or manually turned-off breaker on any module shall initiate a conspicuous display of that condition. It shall not be possible for a module to be without power, without an indication of that condition appearing on the status and alarm panel and initiating the audible alarm, if it is enabled. The load between the phases shall be balanced within 10 percent regardless of the on-off condition of a Mode S sensor and all supporting equipment except for external test equipment.

3.11.1.5 Power supplies.- Each module shall contain all of the power supplies necessary to operate its internal circuitry and meet the requirements established elsewhere herein. All power supplies shall be self-protecting such that a continuous short circuit on the output will not damage any wiring or components and that the output voltage will return to normal promptly upon removal of the short. This protection shall be accomplished without the use of fuses, circuit breakers or relays and shall provide a positive indication on the status and alarm panel during such an overload condition. The Mode S sensor shall be designed to minimize the number of types of power supplies required in the Mode S sensor and supporting equipment. In the event of a partial failure of a power supply, the affected and unaffected units shall automatically remove any remaining companion voltages from components which could be damaged by the loss or reduction of a portion of their normal operating voltages. Partial and full failures shall be reported as required above. Each module's power supplies shall be independently controlled and protected in accordance with paragraph 3.3.2.4.4 of FAA-G-2100. The electrical efficiency of each power supply unit, defined as output power divided by input power, shall be 70 percent or greater under normal operating conditions. All power supplies shall meet or exceed the isolation requirements of FAA-G-2100, paragraph 3.3.2.1.7. Transformers shall be in accordance with paragraph 3.5.35 of FAA-G-2100.

3.11.1.5.1 Regulation.- All power supplies shall be electronically regulated using independent and separate solid-state voltage reference devices for each regulated output voltage. The regulation of one voltage shall not require another output voltage for a bias or a reference, even if multiple output voltages are provided from a single power supply unit. The regulation of each output voltage shall be sufficient to provide the specified equipment performance in any allowable service condition. However, in no case shall an output voltage vary more than ± 0.5 percent as measured with its load varying from 30 percent less than, to 50 percent greater than the normal load, and the supply line voltage varying between the service limits.

3.11.1.5.2 Ripple.- Ripple voltage is defined as the peak-to-peak value of any simple or complex waveform present in the output of a regulated dc power supply; power line frequency components and harmonics as well as switching transients, clock hash and other similar signals are included. Sufficient filtering and decoupling of all power supplies shall be provided such that the normal ripple voltage may double (as the result of power transients, component failures, card removal, module removal or similar failures or maintenance actions) without any circuit or function being disabled or affected by such an increase in ripple.

3.11.1.5.3 Interlocks.- Each module shall be provided with one or more interlocks which removes all voltages of 150V or higher upon the opening of the module for maintenance or adjustment of internal controls. The interlocks shall have a manual bypass which can be activated to prevent interruption of these voltages when the module is opened. The interlocks shall meet the requirements of paragraphs 3.3.1.8.2 and 3.3.1.8.3 of FAA-G-2100.

3.11.1.6. Cabinet supply wiring.- Each Mode S sensor cabinet shall be wired to provide supply line power to all module locations, including locations not populated in certain Mode S sensor configurations and those locations provided for the addition of future modules.

3.11.1.7 Batteries.- In the event that batteries are provided to meet the requirements for operation in the presence of electrical transients (3.11.1.1.1), they shall be located in a single battery compartment for the entire Mode S sensor. This compartment and the selection of the battery type shall be in accordance with FAA-G-2100, paragraph 3.5.1, except that magnesium dry batteries are not permitted. Individual batteries shall be completely sealed and shall not vent gases, liquids or chemicals except in the event of physical damage by external mechanical means. The battery supply shall not be sensitive to orientation of the equipment during operation, transportation or storage. Exceptions to this requirement, such as "keep-alive" batteries for clocks and memories, will be subject to Government approval.

3.11.1.8 Relays.- No electromechanical relays shall be included in the Mode S sensor or its supporting equipment unless specifically approved by the Government. Solid-state relays are permitted if they meet all other requirements herein.

3.11.1.9 Electron tubes.- No electron tubes shall be used without specific approval of the Government.

3.11.1.10 Electronic design.- The Mode S sensor shall be designed to meet the performance, service life, maintainability and reliability requirements established herein using the least complex design and most common components possible which permit these requirements to be met. Solid-state devices shall be used to the maximum extent feasible. The number of different types of integrated circuits, transistors and other semiconductor devices shall be kept to an absolute minimum, consistent with meeting the other requirements herein and with good engineering design. The electronic design shall be such that, whenever possible, a catastrophic failure of a single active device or electrical connection cannot be misinterpreted as a normal or valid condition. Accordingly, memories and other functional elements shall be organized such that the catastrophic failure of an integrated circuit chip shall be able to be detected by the appropriate self-test routine. Parity encoding, one-bit-wide memory chips, error-detecting or error-correcting codes or similar design techniques shall be used as appropriate for memory data, bus data and other similar parallel and serial data transfers to satisfy this requirement.

Semiconductor devices shall be in accordance with 3.5.28 of FAA-G-2100. Micro electronic devices shall be in accordance with 4.1(c) of MIL-STD-454, Requirement 64. Micro electronic devices, in exception to 3.5.20 of FAA-G-2100, may be plastic encapsulated. Marking of the micro electronic devices shall be in accordance with 3.6.4 and 3.6.5 of MIL-M-38510 and shall be legible and complete. All markings shall meet the resistance to solvents requirements of MIL-STD-883, method 2015. Markings shall include date, lot code, and B screening per MIL-STD-883. All micro electronic devices not manufactured in the United States must have approval of the Government prior to use.

3.11.1.11 Grounding requirements.- Requirements for grounding, shielding, bonding and transient protection shall be as specified in FAA-STD-020.

3.11.1.11.1 Grounding practices.- The Government will furnish the earth ground and AC power ground at FAA installation locations. The contractor shall furnish all other grounds as required by FAA-STD-020.

3.11.1.12 Conducted and radiated electromagnetic interference.- The Mode S sensor and supporting equipment provided under the contract shall be designed and constructed to meet the emission and susceptibility requirements as specified in FAA-G-2100, paragraph 3.3.2.6. The Mode S sensor and its supporting equipment shall conform to the electromagnetic interference requirements for Class A3 equipment as specified in MIL-STD-461.

3.11.2 Mechanical design requirements.- The mechanical design of the Mode S sensor, including cabinets, controls, displays and electronic modules and assemblies, shall be as specified in the following subparagraphs.

3.11.2.1 Construction and packaging.- The Mode S sensor and its supporting equipment shall be constructed in a modular fashion to the greatest extent possible, such that the maintenance, reconfiguration flexibility, and other requirements specified herein can be easily met. Except as otherwise permitted herein, the Mode S sensor's modules shall be implemented using plug-in circuit assemblies (CCA), card bins and power supplies in physically independent drawers, hinged panels or slides in a larger cabinet or rack. This requirement does not alter any other requirements (electromagnetic interference, maintainability, reliability, system performance, etc.) established herein. The design shall provide for good accessibility by personnel whose body dimensions fall within the 5th and the 95th percentile as specified in paragraph 5.6 of MIL-STD-1472. The accessibility shall permit easy and convenient operation, calibration, viewing and maintenance of the sensor's panels, controls, displays, units, modules, wiring, CCAs and components as specified by paragraphs 3.3.1.1 of FAA-G-2100. Accessibility may be improved using extenders as specified in 3.10.2.2. Each unit and module shall be able to be removed from the equipment cabinet without requiring the partial or complete disassembly or removal of adjacent units, modules or cabinets. The design shall provide a neat and pleasing appearance, with and without access doors in place. The design and construction of the Mode S sensor shall be subject to acceptance by the Government.

3.11.2.1.1 Physical size.- The equipment specified herein shall be able to be easily installed in buildings with 36-inch (0.9 m) wide doors and ceiling heights of 96 inches (2.4 m). The dimensions of individual cabinets shall not exceed 80 inches (2.0 m) in height, 36 inches (0.9 m) in depth or 48 inches (1.2 m) in width. Smaller dimensions are desirable, providing that accessibility is not degraded. These dimensions exclude handles, cable ducts and connectors, which shall add no more than 2.0 inches (5.1 cm) to these values.

3.11.2.1.2 Cabinets.- Equipment cabinets shall be of high quality, sturdy construction, and shall be accurately and carefully constructed. Each cabinet shall be designed for front access only, to permit location of the cabinets next to walls and other equipment. The design shall not require open spaces on the sides or rear of the cabinet.

The structural strength and rigidity of the equipment units and cabinets shall be such that handling during loading, shipping, unloading and positioning or the prolonged extension of drawers or slides does not result in any permanent set or deformation sufficient to impair the operability or appearance of the cabinets and mechanical parts thereof. Specifically, ease of maintenance, movability of modules or access doors and the integrity of ventilation equipment shall not be impaired. These requirements shall not be dependent on any structural strength or rigidity provided by access doors or removable modules or drawers.

Cabinets and equipment shall not exceed a concentrated floor loading of 700 pounds per square foot (3400 kg/m^2) measured on a 2.5 inch (6.4 cm) diameter circle. The distributed floor load shall be less than 250 pounds per square foot (1200 kg/m^2). Adjustable leveling pads that accommodate floors with variations of up to 0.5 inch (1.2 cm) from level over the cabinet floor area shall be provided at the bases of the cabinets. It is preferred that the cabinets be designed such that it is not necessary to fasten or bolt them to the floor to prevent tipping when the modules are removed or fully extended or both. All access doors shall be mounted using slip pin hinges so that the doors can be easily removed from the cabinets. The opening of an access door and extending of a module shall not interfere with similar operations on adjacent modules. Access to all parts of an extended module shall be possible without undue contortion by maintenance personnel or their exposure to hazardous voltages or mechanical devices. When cabinet lifting points, such as hooks or rings, are installed for convenience in handling, such devices shall be removed by the contractor after installation and replaced with suitably finished cap bolts. Blank panels shall be provided for any unused module space.

3.11.2.1.3 Modules.- Each module shall be separately hung and adequately braced, shall weigh 50 pounds (23 kg) or less (except for the performance monitor display), and shall be able to be removed and replaced by one unassisted technician. The module's power supplies may be separable from the card case when necessary to meet these requirements. The modules with front panel controls or indicators shall contain a minimum of 10 percent spare front-panel space for future additions and modifications. All modules, except the performance monitor display, shall be mounted on slides or drawers which, when fully extended, can pivot up to 90 degrees if required to provide the necessary access to the rear of the module and the wiring, connectors and similar items in the interior of the cabinet. Handles shall be provided to facilitate these operations. Circuit card assemblies (CCA) shall be mounted in an isolated card bin, and mated with a mother board or backplane. The wiring side of the backplane shall be easily accessible for modification or troubleshooting without any disassembly of the module. In the event that swing-out slides are used, their design shall prevent any part of the backplane from coming within 0.5 inches (1.2 cm) of any fixed cabinet part. The backplanes shall have easily removable protective covers. All active components and those passive components with appreciable contributions to the failure rate of a Mode S sensor channel, except for large components such as may be used in the transmitter unit, shall be mounted on the modules to permit easy accessibility. Cabling and ventilation components may be mounted in the cabinet, providing that good access is provided. Spot welding may be used in the manufacture and assembly of the card bins when it is not detrimental to the operation, maintenance or service life requirements herein.

Plug-in CCAs and other plug-in assemblies, such as converters, power supplies and similar items, shall be mounted side-by-side, bookcase style in the card bin. Each card location shall be provided with full length guide strips or

rails to ensure easy installation of the cards and positive alignment of the mating connectors. A minimum of wired-in assemblies shall be designed into the Mode S sensor. In particular, no wired-in CCAs, digital-to-analog converters, external interface signal receivers or drivers, power sensing and control boards or similar assemblies shall be permitted without specific and individual written approval from the Contracting Officer.

3.11.2.1.4 Internal cabling and wiring.- All internal single or bundled wires and cables which interconnect modules or cabinets shall be suitably protected against chaffing, abrasion and flex - or twist-inflicted damage.

This protection shall be independent of the individual wire or cable insulation or jacket. Cables and wires carrying primary line power shall be separated from signal and control cables and wires. Interconnecting wiring between backplanes or mother boards within modules shall enter and egress from connection pins provided near the edge of the backplane specifically for this purpose. Front panel connections and cabling shall be limited to those required for maintenance (3.11.2.8.5.4). Suitable clamps, strain relief and cable dressing facilities shall be provided to protect the cable and connectors (3.11.2.8.5.3) from pinching, wear and abrasion during installation, removal, shipment and maintenance activities.

The provisions of paragraph 3.5.38 of FAA-G-2100 shall apply except that wire as small as AWG 30 is acceptable for logic level signals to and from microelectronic devices. Wire wrap techniques are permissible as specified in 3.11.2.8.3 herein. The contractor shall describe in his proposal the wire coding scheme and soldering techniques to be used; these shall require Government approval.

3.11.2.2 Personnel safety and environment.- The Mode S sensor and all supporting equipment shall meet the requirements of paragraph 3.3.1.8 and its subparagraphs of FAA-G-2100 except as modified below. No radioactive parts, materials or elements are permitted in any equipment specified herein. Noise level limits shall be as specified in paragraph 3.3.1.7 of FAA-G-2100 with the values of Table III, FAA-G-2100 modified as follows:

NOISE LEVEL LIMITS

FREQUENCY BANDS (Hz)	NOISE LIMITS (dB)
20 - 150	89
150 - 300	82
300 - 600	76
600 - 1200	73
1200 - 2400	70
2400 - 4800	68
4800 - 20000	66

The Noise level limits shall apply to the simultaneous operation of all equipment including the I/O devices (3.7.2.4). Electromagnetic radiation

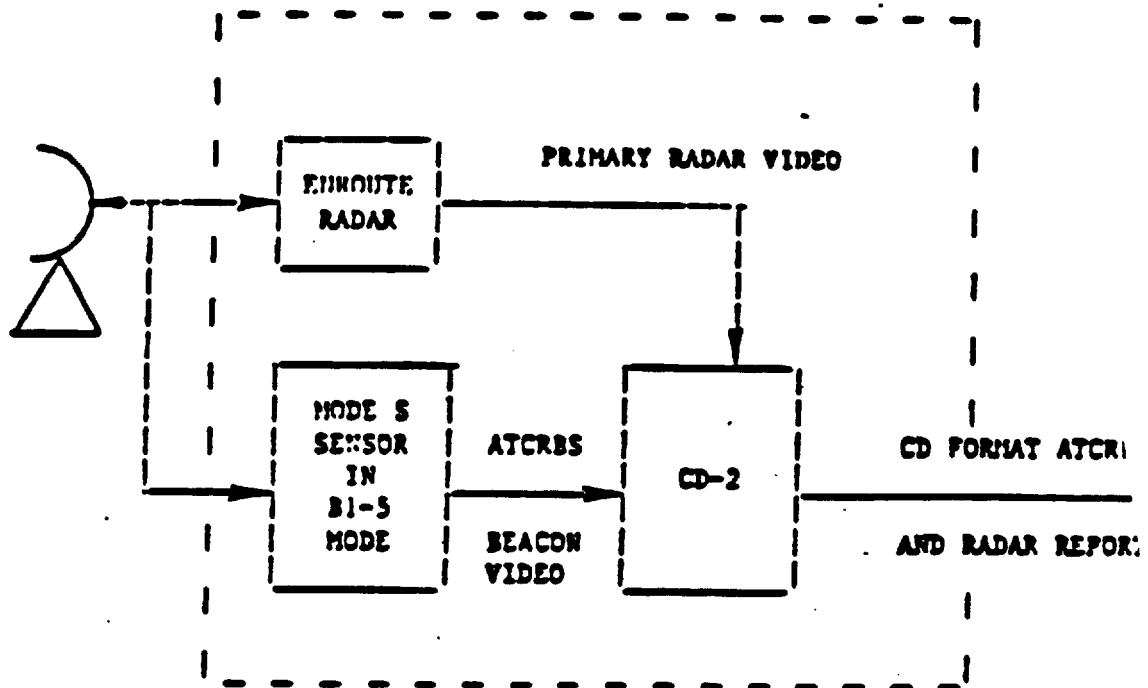


Fig. XI-2 Initial CD-2/Mode S Interface-Without CD-2 Modification.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-5

-420-

* This page intentionally unused *

illumination of 40 footlamberts (137 cd/m^2), the amount of room light at the darkest interior cabinet location that has wiring, connectors or module mounting hardware is 25 footlamberts (86 cd/m^2) or more. The lights, if provided, shall automatically activate when the interior of the cabinet is available for access. Manual control of the lights shall also be provided.

3.11.2.3 Convenience outlets.- Two recessed duplex convenience outlets shall be provided on the bottom front of each cabinet. The outlets shall meet the requirements of paragraph 3.3.2.1.4 of FAA-G-2100.

3.11.2.4 Cabinet ventilation and cooling.- The thermal design of the Mode S sensor and supporting equipment shall be in accordance with paragraph 3.3.1.9 (and associated subparagraphs) of FAA-G-2100 as amended below. No glass wool air filters shall be permitted. The thermal design shall accommodate continuous operation over the range of service conditions (3.11.1.2). All blowers, vents and related cooling equipment necessary for effective ventilation and cooling of the equipment shall be provided. Each cabinet requiring forced ventilation shall contain its own blower system. The design shall be such that with any or all access doors open and any or all modules extended or removed, the equipment shall not develop hot spots exceeding 55 degrees Celsius during an eight hour period when the ambient temperature is +30 degrees Celsius.

The air intakes shall be near the floor and their associated filters shall be accessible without opening any access doors. The exhaust outlets shall be at the top of the cabinet and shall prevent foreign objects from entering the cabinet through the exhaust opening. Individual module ventilation equipment may also be used if necessary to meet these requirements. The air intakes and outlets shall be designed to accommodate a recirculating air supply (not a part of this specification).

Motors shall be reliable, continuous-duty units with good accessibility for maintenance and testing. The motor speed shall not exceed 3450 RPM. The bearings shall be roller or ball bearings or equivalent. The impellers shall be dynamically balanced. Each motor shall be protected as required by FAA-G-2100, paragraph 3.5.21, except that no fuses or multiphase motors shall be permitted. Waviness or other efficient motor design shall be used where possible.

3.11.2.5 Overheat condition detection and reporting.- The Mode S sensor shall contain at least one thermal sensor per power supply or one sensor per module, whichever yields a greater number of sensors. In addition, one sensor shall be located in the exhaust air flow of each cabinet with forced ventilation. The sensors shall provide the temperature of each location to the status monitor. It is permissible to use a single digital thermometer and multiplex the various inputs. The status monitor shall contain two factory-established thresholds for each sensor location. The thresholds shall provide indications of normal, elevated and overheat temperature conditions. An abnormal condition at any sensor shall be indicated by one or both of the temperature alarm indicators (elevated and overheat) on the status and alarm panel and reported to the sensor performance monitoring function (3.4.10.2.5).

3.11.2.6 Finishes.- All Mode S sensor equipment shall be finished as required by paragraph 3.7.7, and all applicable subparagraphs, of FAA-G-2100. In no instance, shall a finish interfere with the grounding, electromagnetic interference, performance or mechanical operation of any portion of the Mode S sensor. The cabinet exteriors shall be finished with color number 20372 of FED-STD-595, and shall have a smooth semi-gloss surface.

3.11.2.7 Dissimilar metals.- Dissimilar metals exhibiting an electrolytic potential difference greater than 0.4 volt when immersed in a three percent sodium chloride solution shall not be used in intimate contact unless protected against electrolytic corrosion with appropriate protective methods and materials.

3.11.2.8 Mechanical design of electronic components.- The mechanical designs and mounting of the electronic assemblies and components used in the Mode S sensor and supporting equipment shall be as described in the following subparagraphs.

3.11.2.8.1 Backplane.- Using the appropriate special tools and ancillary items (3.10.2.3), the backplanes or mother boards into which the circuit card assemblies (CCA) are inserted shall be able to be rewired in the field to change the distribution of signals within a module. Standardized power distribution busses shall be established. The backplane shall be suitable for connection of test equipment as specified in 3.10.

3.11.2.8.2 Circuit card assemblies.- The CCAs used for digital logic integrated circuits shall incorporate dual-in-line packages wherever feasible. The individual integrated circuits (including PROMs, processors, etc.) shall be able to be removed intact and replaced using test equipment recommended for, or provided with the Mode S sensor. CCAs containing discrete semiconductors, linear integrated circuits and their supporting components shall be able to have their active devices removed and replaced in accordance with these same requirements. All CCAs shall be able to be repaired when any component thereon fails, for the full service life of the Mode S sensor in its normal operating and maintenance environment.

CCAs with printed wiring shall be in accordance with 3.5.23 of FAA-G-2100, except that 3.5.23b and 3.5.23c therein do not apply.

Conformal coating of printed wiring CCAs is not required unless otherwise required to meet environmental conditions. MIL-STD-275 shall apply to uncoated printed wiring CCAs except for paragraphs contained therein which specifically address conformal coating. Minimum conductor width on the finished uncoated printed wiring CCAs shall be 0.010 inch unless otherwise approved by the government. For uncoated printed circuit CCAs, the Table below shall be used for determining minimum spacing between conductors, between conductor patterns, and between conductive materials (such as conductive markings or mounting hardware).

Voltage between conductors DC or AC peak (volts)	Minimum spacing
0-10	0.015 inch
11-75	0.020 inch
76-150	0.025 inch
151-300	0.050 inch
301-500	0.100 inch
Greater than 500	0.0002 (inch per volt)

The minimum number of types of CCAs necessary to implement the requirements herein shall be utilized. All CCAs shall be able to be inserted and removed with power applied to the module without causing oscillations or damage to any components and without requiring removal and reapplication of power to reinitialize the operation.

3.11.2.8.2.1 Component mounting.- All semiconductor and integrated circuit components shall be mounted as specified in paragraph 3.4.8 of FAA-G-2100, unless other mounting techniques (e.g., sockets) are necessary to meet other requirements herein. In the event that such deviation is necessary, the contractor shall obtain the Contracting Officer's approval by submitting the appropriate technical justification, including the changes, if any, to the calculated reliability and service life of the equipment, indicating values with and without the deviation. All electronic parts shall be attached such that each part is amenable to removal and replacement.

Wrapped circuit connections meeting the requirements of 3.11.2.8.3 or multi-layer soldered wiring may be used as discrete point-to-point wiring. Regardless of which of these two approaches is chosen, its strength, reliability wear-resistance and modification characteristics shall be satisfactorily demonstrated to and approved by the Government before it is used in production equipment.

3.11.2.8.2.2 CCA baseboard.- The CCAs shall be sufficiently rigid to prevent damage to the conductive patterns during manufacture and subsequent handling during maintenance and testing. In the event that a mechanical frame is utilized to achieve this strength or to protect the wire-wrap or multi-layered wiring or both, the frame shall be approved by the Government prior to its use in production equipment.

All CCAs shall provide a convenient and positive means of removal from and insertion into the module's card bin without the use of a separate tool. Handles, finger holds or similar means may be used. The selected technique shall permit easy removal and insertion without damage or undue strain on the module frame, the components and wiring on the CCA, or the connectors on the CCA or module. The maximum insertion or extraction force of any CCA or other plug-in assembly shall be less than eleven pounds (5 kg) per extractor.

All CCAs shall conform to all applicable paragraphs of FAA-G-2100 and reference designations shall be as specified in 3.11.2.10 herein.

3.11.2.8.3 Wrapped connections.- Wrapped wire connections may be utilized on backplanes and digital logic CCAs to provide the required modification ability. Wrapped connections shall meet all requirements of paragraph 3.5.30 of FAA-G-2100.

Wire wrapped backplanes and wire wrapped digital logic CCAs shall not be conformal coated.

3.11.2.8.4 Controls.- All circuits shall be designed so that no damage can occur when the equipment is operated with any possible setting of the internal adjustments or operating controls. Protective devices shall not be activated with the activation of any operational control. There shall be no noticeable lag between the activation or adjustment of a control and the effect of the

activation or adjustment. All continuous or multi-position controls shall have calibration markings to permit setting them to predetermined positions, except where it can be demonstrated to the Government that such markings are unnecessary or impracticable. Motor-driven switches and controls are prohibited.

Frequently used or calibration controls on the interior of the Mode S sensor shall be accessible without disassembly or otherwise making the affected module inoperative. Frequently used controls on CCAs shall be accessible without removing the assembly from its normal position. All controls shall be mounted so as to minimize the possibility of personnel contacting high voltages or hot components, and shall be in accordance with FAA-G-2100, paragraph 3.5.5.

The term "simple internal means" as used herein shall indicate that the specified function shall be controlled by an internal control or other means. Acceptable techniques include wire straps, plug-in jumpers, dual in-line-packaged (DIP) switches and rotary controls mounted on the appropriate CCA. The term "simple and convenient internal means" shall include all of the techniques described above except that wire straps or jumpers are prohibited and the switches or rotary controls shall be accessible without placing the CCA on an extender or otherwise disrupting the module's operation.

3.11.2.8.5 Connectors. The connectors furnished with the equipment shall conform to the requirements of the following subparagraphs and to paragraph 3.5.8 and its subparagraphs of FAA-G-2100. Test jacks shall accommodate a test probe having a diameter of 0.080 ± 0.001 inches (2 ± 0.03 mm).

3.11.2.8.5.1 CCA connectors. The number of pin connections per circuit card assembly shall be 480 or less per edge, not including test points. The connector receptacles and the CCA connector shall be polarized and keyed such that CCAs can be inserted with the correct sense only, and that only the proper type of CCA can be inserted in a given location. The keying method shall not affect the number of available connector pins. In the event that polarizing keys are used, they shall not be able to be removed during normal insert-remove operations. The particular edge board (one-part) connector to be used (3.11.2.8.2.2) shall be approved by the Government before it is used in any deliverable equipment. Mating connectors shall be designed for repeated use and long-term reliable performance without jamming or damage as the result of frequent insertion of card assemblies. At least 100 casual (as contrasted with "careful") insertion and removal cycle of the CCAs shall be possible without damage or degraded operation or reliability.

3.11.2.8.5.2 CCA test points. Sufficient test points and connectors shall be provided on all CCAs to meet the automatic diagnostic requirements of the Mode S sensor card tester (3.10.2.1).

3.11.2.8.5.3 Inter-module and inter-cabinet connectors.- The signal and power cabling between modules and between cabinets shall be provided with separate connectors to permit separation of cabinets and removal of modules. A single set of connectors shall be provided at the cabinet and module interfaces. Terminal blocks may be used for inter-cabinet cables, in which case they shall be protected with a removable plastic cover with round access holes over each terminal for screwdrivers or test probes. All internal cabling shall include provisions for testing the continuity of each conductor. Terminal blocks, where used, shall meet this requirement with the access specified above, and shall be in accordance with paragraph 3.5.34 of FAA-G-2100. Connectors, including those for ribbon and other multi-conductor cables, shall provide test points for in-circuit signal observation or injection, or shall have test points available on backplane or CCA entry points for each conductor. All inter-module and inter-cabinet connectors shall provide for a positive and reliable connection in the presence of reasonable physical stress in the area of the connection. Spare pins (conductors) equal to at least 20 percent of those utilized, but not less than two of each type, shall be provided at each connection.

3.11.2.8.5.4 Module test points.- Test points shall be provided for measurement and observation of such voltages and waveforms as are needed for the checking of performance and for the maintenance of individual modules. Test points for signals requiring frequent observation, adjustment or alignment shall be provided on the front panel of the module or other assembly. The test points for these particular signals shall be accessible without interruption of the circuit operations or the use of extender cards. All other test points shall be located on the card bin, backplane or edge connectors of CCAs as appropriate. Each test point shall be suitable for "hands-off" connection of test equipment probes and clips. The extender card (3.10.2.2) may provide test points to meet this requirement for CCAs. All test points shall be identified with a TP number. Those permanently connected to a signal shall have a voltage, waveform, or other descriptive title adjacent thereto, except where limited by space considerations, as on a CCA. Power supply output voltages, internal data and address busses, clocks, and input-output signals at a minimum shall be available at each module's test points. All test points shall be isolated such that test equipment loading effects, including short circuits, do not affect the source of the test point data. The equipment shall be designed to provide access to the signals and connections for the test equipment as may be required for expeditious maintenance, calibration, and repair.

3.11.2.8.6 Front panel indicators.- All front panel indicators, including the power on-off indicators on each module and the status and alarm panel indicators, shall be in accordance with paragraph 3.5.17 of FAA-G-2100, except for indicator color and except that light-emitting diodes or other display media meeting the requirements herein may be used.

FAA-E-2716

3.11.2.8.7 Front panel controls.- The front panel controls of the Mode S sensor shall be designed for reliable service during the rugged conditions of nearly constant operation and use. All control assemblies shall be maintainable and repairable by site technicians.

The data entry devices shall be simple, reliable units which meet the applicable operating requirements specified above for the cursor control. If a keyboard is used, it shall be a self-contained, replaceable unit capable of meeting the service life requirement under constant daily use.

3.11.2.9 Cable entry and exit locations.- All power, signal and ground cables connecting the basic Mode S sensor cabinets to external equipments shall enter and exit the Mode S sensor at the top of the cabinet or cabinets containing the control and interface modules. A single cable connection area shall be provided to minimize external duct work. Cable entrances and exits shall be designed to enable advantageous routing of cables within and between cabinets from the standpoints of accessibility, serviceability, appearance of the installed equipment and noninterference with the activities of operating and maintenance personnel. All necessary connectors shall be provided. All special tools required for cable fabrication or connector removal or installation shall be provided as specified in 3.10.2.3. The length of the external equipment cables shall be as determined by the Government for the individual site receiving the particular Mode S sensor.

3.11.2.10 Reference designations and marking.- All test points, cable terminations, jacks, controls, modules, card bins, assemblies, and front panels shall be clearly and permanently marked to show their intended functions and locations, designations and titles. The reference designations shall be in accordance with section 3.8 of FAA-G-2100 except that section 3.8(b) of FAA-G-2100 shall not be used. The marking shall be accomplished as specified in section 3.9 and all applicable subsections of FAA-G-2100, except that the requirements of subsections 3.9.1 are not applicable where it is impractical, such as with automatic parts insertion devices. Line drawings in the equipment's instruction book shall be used to convey the reference designations and positions of parts on CCAs and similar assemblies. Each CCA and any other plug-in assembly shall include identification markings which identify the basic circuit function and reference designation of the unit of which it is a part.

3.11.2.11 Moisture pockets.- The equipment shall be constructed in accordance with paragraph 3.3.3.5 of FAA-G-2100. Components and wiring subject to damage by immersion in water, with power applied or not, shall not be mounted in the lower four inches (10 cm) of any cabinet.

3.11.2.12 Other requirements.- The other requirements of FAA-G-2100, paragraphs 3.4 through 3.11, which are not specifically called out elsewhere herein, shall apply.

-427-

3.12 Computer programs.- The contractor shall deliver all operational, support, and test software programs required to meet the requirements of this specification. All deliverable programs shall be provided in a format as required by the Mode S sensor equipment to provide the operational, maintenance, diagnosis, test, and analysis functions required herein. All programs, including source code, shall also be delivered in the format required for use, modification, and long-term storage at a program support facility (appendix II).

All computer programs delivered with the Mode S sensors shall, when loaded, generate a load message to the operator to supply the program name or function, the program release and the revision level and the site ID if applicable. The memory data from which this load message is generated shall not be destroyed by normal execution of the program.

- # All computer programs (except firmware) delivered with the Mode S sensors shall provide for minor keyboard site adaptation changes prior to execution of the program and a means shall be provided for recording a revised or duplicate program in the same format as delivered. The site adaptable parameters shall be set through mnemonic keys. Direct modification of the program or the sensors' memory shall only be permitted through the use of a connected programming/sensor support facility (appendix II). There shall be no other means of modifying the program or the sensors' memory provided at the sensors. #

This paragraph and all its subparagraphs shall apply to all software/firmware delivered under this specification. The term "software/firmware" as used in this specification shall apply to all deliverable items having one or more of the following characteristics:

- (a) Computational and control logic represented in a higher order language or assembly language form and defined as source code to be interpreted, assembled or compiled into machine executable form.
- (b) Executable program instructions at the microcode or direct machine executable levels.
- (c) All data representations required by executable program logic.

These deliverable items are further identified as being processed/executed on computational/control hardware. This hardware consists of Central Processing Units (CPU's) or programmable controllers/devices or both, whether used as general purpose (as in the computer subsystem) or dedicated (as in the communications or front end subsystems) hardware.

All items meeting the above criteria shall be subject to the software/firmware requirements of this specification. Exceptions shall be made only upon written authorization by the Contracting Officer.

The terms software or firmware, throughout this specification, refers to the term software/firmware. #

3.12.1 Functional programs.- The contractor shall provide a complete set of all the programs that are required to enable the Mode S sensor operational equipment and peripherals to accomplish the functions described in this specification. These operational programs shall include the actual programs required to perform the processing functions as well as the operational and diagnostic self-test functions required herein. Subprograms to operate with the functional program shall be provided as required to maintain continuous operation and confidence in the Mode S sensor's performance. The functional programs shall be identical for all Mode S sensor configurations. All adaptation to unique site conditions and parameters shall be accomplished with changes to the initialization data as implemented by the internal means specified in the applicable paragraphs herein, or by the entry of data from the operator's keyboard device (3.8.3.1(a)) or both. The functional programs shall be provided with the Mode S sensor when it is delivered.

3.12.2 Support programs.- See 3.8 and appendix II.

3.12.3 Software design and development.- This section provides requirements for the attributes of the Mode S software and the characteristics of the software design and development techniques. The primary objectives of these requirements are to ensure correctness, reliability, efficiency, and maintainability of the software. These requirements shall apply to the design and development of all software. The following paragraphs contain requirements to perform software development planning and software design using a structured design technique, and perform software implementation using a single high-order language (HOL).

3.12.3.1 Development planning.- All software shall be designed and implemented in accordance with a Government approved Software Development Plan prepared in accordance with 3.13.1.2.5.1.

3.12.3.2 Software design.- All Mode S software shall be designed in accordance with design standards approved by the Government. In addition to paragraphs of this specification, the software design shall accommodate the following requirements:

- (a) Identical software, adapted to the local resources, environment, and workload, shall be installed in each site. Local "patches" to executable code and data tables shall not be used to meet this requirement.
- (b) Design emphasis shall be placed on reliability, error detection, fault tolerance, and recovery from abnormal conditions. Techniques used to meet this requirement may include formal verification of critical software, continuous checking for data consistency, redundant software for essential functions, and duplicate storage of data and programs.

-429-

- (c) The design shall support system modification, enhancement, and expansion throughout the expected lifetime of the Mode S. Provision shall be made in instruction code, data tables, and data base, to accommodate additional functions, new equipment, and new data.
- (d) The software design shall provide logical and physical data independence. Changes made to the logical structure of the data shall not impact the application programs. Changes made to the physical structure of the data shall not impact the logical structure of the data or the application programs. The Mode S sensor software shall permit changes to both the form of storage and to the position of data in the storage without impact to the application programs or the logical structure of the data.
- (e) The software design shall provide data integrity. It shall protect data from accidental loss or damage.
- (f) The software design shall provide a common and controlled approach to adding new data and to modifying and retrieving existing data. It shall provide logical data to the application programs as required. It shall provide status information to the application programs on the outcome of data requests including error indications.
- (g) The software design shall assure that the system is initialized to a correct, well defined state upon recovery from a fault, and that all processing interrupted by a fault is properly continued after recovery.
- (h) The software design shall incorporate a standard off-the-shelf operating system with a standard compiler, loader, librarian, and other standard debug and utility tools.

3.12.3.2.1 Software architecture.- The Mode S software requirements specified herein shall be translated into a top level design and architecture.

The architecture shall minimize the complexity of interfaces between software modules and keep unrelated functions separated.

The software requirements shall be decomposed into computer program configuration items (CPCIs), computer program components (CPCs), modules, routines and lines of code using a top down approach. There shall be design traceability between successively more detailed levels of abstraction from the most abstract level to a level sufficient for code implementation. Each level shall be complete and independent containing definitions of data and the operations on the data.

This space intentionally unused.

- # 3.12.3.2.2 Module attributes.- The software design shall be functionally and #
operationally modular to:

- (a) Facilitate system expansion, modification, and configuration control.
- (b) Enhance system reliability for facilitating fault detection, diagnosis, containment, recovery, and fault-tolerant behavior.
- (c) Facilitate data base changes to the lowest practical level without large program reassemblies.

Each module shall perform a single unique function, with inputs, outputs, and intermodule interfaces clearly defined. Each module shall be separately compilable.

Each module shall consist of a specification part, data declarations, and sequence of statements. The specification part shall contain the information necessary to use the module without describing the internal details of how the module operates. The data declaration shall define the logical entities needed by the module, and the sequence of statements shall define the operations to be performed.

Only statements within a module shall access private data of that module. Other modules shall access through interfaces provided by the module.

- # 3.12.3.2.3 Design representation; - The design shall be represented in a #
manner which ensures traceability to the requirements of this specification. #
The representation shall be maintained as part of the design data base.

3.12.3.2.4 Special tools and techniques.- Automated design support tools shall be used to record, analyze, and maintain the Mode S software design. These tools shall provide:

- (a) Traceability of software system components to software requirements.
- (b) Configuration control and tracking of changes in the design and software requirements.
- (c) Completeness and consistency testing of all software modules.
- (d) Modeling and simulation to support processing resource allocation and to predict system performance under varying workloads.
- (e) The means to verify adherence of the design to software design standards.

- # (f) The means to indicate in the design representation that a design #
feature is incomplete and to later identify and track all such
incomplete design features.

-431-

- (g) Various printed outputs such as source listings, error lists, cross-reference lists, flowcharts, design history logs, etc.

The tools shall be applicable throughout the software development and maintenance life cycle. They shall address all aspects of software design including algorithms, data structure and files, and interfaces. The tools shall encourage and facilitate design of software in accordance with approved design techniques and standards.

All special tools and techniques used to develop the software, and necessary to maintain and further develop the software, shall be delivered to the Government as part of the sensor programming support facility (3.8.4). The development, documentation, and testing required by this specification do not apply to these special tools.

3.12.3.3 Software documentation/implementation.- All software shall be documented in accordance with the requirements specified in 3.13.1.2.5. All software shall be implemented in accordance with the standards established in the Software Development Plan (3.13.1.2.5.1).

3.12.3.3.1 Module attributes.- All modules shall be implemented with one entry and one exit with the exception of error conditions and shall be written using only the following control constructs.

- (a) SEQUENCE Sequence of two or more operations.
- (b) IF-THEN-ELSE Conditional branch to one of two operations and return.
- (c) DO-WHILE Operation repeated while a condition is true. Test is before operation.
- (d) DO-UNTIL Operation repeated until a condition is true. Test is after operation.
- (e) CASE To select one of many possible cases.
- (f) FOR Operation repeated for a fixed number of iterations.
- (g) BREAK Used to support the "CASE" statement in some HOL languages.

A language preprocessor/precompiler shall be implemented if the language compiler used does not contain structured programming control logic to process the constructs cited above. The preprocessor/precompiler shall check the source code syntax and translate it into compilable code prior to invoking the source compiler.

3.12.3.3.1.1 Additional module attributes.- A module shall have the following additional attributes:

- (a) A program shall contain the code required to implement a single, well-defined function and shall consist of a maximum equivalent of 200 executable high-order language statements.
- (b) All source code shall be indented to clearly denote logical level of constructs.

- (c) All segments shall have sufficient annotation, i.e., comments to explain inputs, outputs, branches, and other items not obvious to the code itself. Explanatory notes shall be uniformly indented.
 - (d) Non-executing statements shall be grouped in one area in each module to simplify debugging and maintenance.
 - (e) Data declarations shall be grouped and arranged in a meaningful order in the code, e.g., columnar rather than a horizontal string.
 - # (f) Data names and procedure labels shall be mnemonic or descriptive and procedure labels shall describe the function it performs. #
 - (g) Each line of source code shall contain one statement only.
 - (h) Formats for error and diagnostic messages shall be standardized and shall require no additional interpretation, such as table lookups.
 - (i) Loop indexes shall not be altered during loop execution.
 - (j) Unnecessary assignment of a constant value to a variable (especially within a loop) shall be prohibited.
 - (k) Code shall be written so that no code shall be modified during execution.
 - (l) Modules shall not share temporary storage locations of variables.
 - (m) Each module shall be uniquely identified.
 - (n) Except for error exits, each module shall have a single entry point and a single exit point.
 - (o) Complicated expressions, such as compounded negative Boolean expressions, and nesting beyond three levels shall be avoided.
 - (p) Mixed mode numerical expressions shall be avoided.
- # 3.12.3.3.2 Code representation.- A single system high order language (system HOL) shall be used for the computer subsystem and for all codes required for the Mode S System including operational, monitor, training and support code.

Deviations from this requirement that are necessary to meet the overall specification requirements, or are beneficial to the Government, shall be requested in writing, with contractor justification, and submitted to the Government. Justification shall include at least the following information:

- (a) Purpose of Deviation.
- (b) Application to the system.

-433-

- # (c) Supporting analysis showing that requirements are met and indicating the benefits to the Government.

- (d) Delivered product description, including documentation.

All deviations, except for specific approved cases, shall be developed and implemented in accordance with the requirements specified herein. #

3.12.3.3.3 Special tools and techniques.- Automated tools shall be used to support the software development process. These tools shall provide or facilitate the use of:

- (a) Software configuration management.
- (b) Common data-type definitions and procedure libraries.
- (c) Cross-reference listings and indices.
- (d) Source code reformatter program to provide a uniform and consistent style.
- (e) Measurement of program size and complexity.
- (f) Module interface checking and identification of other program anomalies.
- (g) Module testing and debugging facilities, including data recording and reduction.
- # (h) Compilation, linking and loading. #
- (i) Data management.
- (j) Verification of adherence to software programming standards.

- # All software tools or techniques used to support software implementation along with sufficient documentation to allow an operator to understand and use these tools shall be delivered to the Government as part of the sensor programming support facility (3.8.4). The development, documentation, and testing required by this specification do not apply to these special tools. #

- # 3.12.3.4 Commonality.- The Mode S design shall maximize the use of common software modules consistent with minimization of overall life cycle cost.

This space intentionally unused. #

3.12.3.5 Software reliability.- Mode S software shall have the following reliability characteristics:

- (a) Fault Avoidance - The software shall be specified, designed, and implemented to achieve high reliability in accordance with the detailed software design and construction requirements presented in paragraph 3.12.
- (b) Fault Detection - The Mode S system shall have the capability to detect its own software-induced failures. Software fault detection techniques used in the Mode S shall provide for detecting software failures before the effects of the failure compromise specification performance requirements. All software failures must be detected and services restored within the specified response time intervals associated with the function(s) that the software supports.
- (c) Fault Tolerance - The software shall provide fault tolerant mechanisms that ensure continuing required functions without causing an interruption in service. These techniques include, but are not limited to (a) recovery block schemes (which cause switching to a spare block of code) and (b) protective redundancy (which includes multiple storage of critical variables and data, diagnostic program, and automatic program reloads).
- (d) Fault Containment - The following fault containment considerations shall be incorporated into the Mode S software design.
 - (1) The software design shall provide protection against the propagation of software errors. No information shall be passed unless error boundary conditions are satisfied.
 - (2) The system shall protect itself against errors in operation or data which may be introduced as the result of incorrect synchronization of software.

3.12.3.6 Software maintainability.- Mode S software shall have the following maintainability characteristics:

- (a) Software testing, performance monitoring, and maintenance operations shall not interrupt normal system operation.
- (b) Mode S software shall be designed as a collection of software modules.
- (c) Each software module shall be written in the same high-order language.
- (d) Each software module shall include error detection and exception handling capabilities.
- (e) Each module shall be separately maintainable.

- # 3.13 Documentation.- The contractor shall provide all necessary services and materials required to develop, prepare, and deliver to the Government the documentation specified herein, in accordance with the formats, quantities and submittal schedules specified by the contract schedule. All documentation specified herein shall be maintained current throughout the contract life cycle reflecting the current Government approved version of each document. Documents which have been formally accepted by the Contracting Officer and require revision as a result of a Government approved engineering change request (ECR) shall be subject to the same requirements as those imposed on the initial submittal with regard to format, quality and quantities. Specifications subject to change as a result of a Government approved ECR shall be revised and processed in accordance with the requirements specified by paragraph 3.3 of MIL-STD-490. Engineering drawings and associated lists subject to change as a result of a Government approved ECR shall be revised and processed in accordance with the requirements specified by Chapter 500 of DOD-STD-100. All other documents subject to change (e.g. plans, manuals, reports or procedures) shall be processed in the form of replacement or change pages or by revision of the entire document when more than 50 percent of the document is affected by the revision.

All documents developed, prepared, updated or delivered shall be identified in accordance with the following requirements:

- (a) Technical documents shall be numbered and dated on each page. The identification number, with the date below it shall always appear at the top of the page opposite the binding edge. The number shall not contain more than fifteen characters, excluding dashes and revision letter. Revision letters, starting with "A" for the first revision, and assigned alphabetically for each succeeding revision, shall follow the document number. Letters I, O, Q, S and Z, can be confused with numerals and therefore shall not be used.
- (b) Engineering drawings and associated lists shall be identified in accordance with the requirements specified by chapter 400 of DOD-STD-100.

The legibility and clarity of all delivered reproducibles shall be in accordance with the requirements of paragraph 3.9 of DOD-D-1000. The media (microfilm or diazo prints) selected by the contractor shall comply as a minimum with the following:

- (c) Microfilm shall comply with the requirements of MIL-M-9868, as applicable to Type II, Class 3, Diazo type microfilm.
- (d) Diazo prints shall comply with the requirements of MIL-D-5480, as applicable to Type I, Class 2 and Type II, Class 2 diazo prints. #

All documents shall be prepared using correct English and a minimum of abbreviations and acronyms. Correct spelling (e.g. "through" instead of "thru") and punctuation shall be used in clear, direct sentences. Effective and unambiguous communication of the intended information shall be the goal of each document.

- # 3.13.1 System documentation.- The following subparagraphs specify the documentation requirements, including administrative data requirements, applicable to the Mode S sensor program and its acquisition process. Such additional information as may be requested by the Government in accordance with paragraph 4.6 and 4.7 of FAA-G-2100 shall be provided.

3.13.1.1 Program management status reports (PMSR's).- The contractor shall prepare PMSR's in accordance with the following subparagraphs, and submit same to the Contracting Officer in accordance with the contract schedule.

3.13.1.1.1 Initial PMSR.- The initial PMSR shall consist of (a) a management plan; and (b) a program schedule inclusive of the contractor's program control procedures. On approval by the Contracting Officer these documents shall become the Master Program Plan and Schedule. The contractor shall maintain and update these documents throughout the contract life cycle, and these documents shall form the basis for the preparation of all subsequent PMSR submittals.

3.13.1.1.1.1 Management plan.- The management plan shall be in accordance with Data Item Description DID-DI-A-5239.

DID DI-A-5239 is modified as follows:

- (a) Block 9, delete references to DODI-7000.2 and DOD 5220.22
- (b) Paragraph 10.1, delete last sentence was "Management requirements shall be in accordance with DODI 7000.2, DOD 5220.22, as applicable."
- (c) Paragraph 10.2, revise to read "other subjects which shall be addressed are as follows:
 - (1) design control of design documentation
 - (2) reliability/maintainability
 - (3) configuration control
 - (4) standardization
 - (5) quality control
 - (6) provisioning
 - (7) control of Government property
 - (8) delivery procedures
 - (9) factory tests
 - (10) fabrication
 - (11) warranty and repair services"
- (d) Delete paragraphs 10.7 through 10.7.2 in their entirety.
- (e) Paragraph 10.8, delete the word "CDRL (DD 1423) and replace with the words "contract schedule".

3.13.1.1.1.2 Program schedule and control procedures.- The contractor using the Work Breakdown Structure (WBS) provided in the Request for Proposal shall provide a detailed WBS in accordance with the requirements of MIL-STD-881 and a program performance milestone schedule, inclusive of a supporting narrative which relates the WBS to each task and event depicted on the program schedule. The program schedule shall address all deliverable items, activities which require Government action and significant tasks and events which must be accomplished. As a minimum the following shall be furnished:

- (a) Program schedule depicted in either a barchart or milestone format. It shall be divided into three phases and shall address both contractor and subcontractor effort related to: equipment/software design and development phase; presubmission test and evaluation phase; and production phase.
- (b) Program Evaluation Review Technique (PERT) chart prepared in accordance with FAA-STD-007 or equivalent type network keyed to the applicable WBS number and/or event. The PERT chart shall define the programs critical path inclusive of the analysis performed by the contractor which determined the critical path. The contractors usual internal management analysis technique (PERT equivalent) may be used in lieu of PERT provided that: (1) the required data is as requested above and is clearly presented; and (2) the contractor requests from and is provided prior approval to use the PERT equivalent by the Contracting Officer.
- (c) A complete set of subcontractor schedules, and a listing of the components to be supplied, including critical items and respective lead times. The contractor shall also describe the methodology inclusive of procedures which will be utilized to manage and control the participating subcontractors.
- (d) The contractor shall provide a detailed explanation of the program control methodology including procedures which will be effected to ensure on schedule completion of all program activities, a description of the procedures which provide management with timely visibility relative to potential or real problem areas and the methodology used by management to minimize or eliminate schedule impacts resulting from those problem areas.

3.13.1.1.2 PMSR's during design and development.- PMSR's submitted during design, development, fabrication and test of the first production article shall include three distinct sections.

3.13.1.1.2.1 Section I, program status.- Section I shall consist of a narrative which shall for each reporting period address: (1) the status of the contractor's work progress for the reporting period relative to the design, development, fabrication, and test effort of each Mode S Configuration Item (CI) and Computer Program Configuration Item (CPCI); and (2) the status of all deliverable program documentation and training effort. Included in Section I shall be an index of all technical memoranda generated and drawings prepared for the reporting period, this index shall be cumulative, maintained and updated as result of changes or new additions, and shall be submitted in all subsequent PMSR submittals.

3.13.1.1.2.2 Section II, program schedule.- Section II shall consist of an updated PERT chart or equivalent type network (reference 3.13.1.1.1), updated program schedule, and updated subcontractor schedules.

3.13.1.1.2.3 Section III, problem areas.- Section III shall address each known potential or actual problem area and the actions taken by the contractor or required by the Government to resolve the problem(s). In those instances where a problem will result or is expected to result in a schedule impact the contractor shall describe the action or "work arounds" implemented to minimize the impact to the program.

3.13.1.1.3 PMSR's during production.- PMSR's submitted during the production phase of the program shall consist of at least three distinct sections.

3.13.1.1.3.1 Section I, program status.- Section I shall consist of a narrative which shall for each reporting period address the contractors work progress relative to the following areas: production; testing; site installations; spares support; training; maintenance; engineering change request (ECR) activity; and instruction books.

3.13.1.1.3.2 Section II, program schedule.- Section II shall consist of an updated milestone schedule reflecting the current status of ongoing production effort and support functions.

3.13.1.1.3.3 Section III, problem areas.- Section III shall address all known potential or actual problem areas, and those actions taken by the contractor or required by the Government to resolve the problem(s). In those instances where a problem will result or is expected to result in a schedule impact, the contractor shall address the actions or "work-arounds" implemented or to be implemented to minimize the impact to the program.

3.13.1.2 System design data.- System design data shall be submitted for Government review, comment and approval in accordance with the contract schedule. The contractor shall perform a system requirements analysis which shall relate specification requirements to the design data. A System Requirements Analysis Report (SRAR) shall be prepared which shall describe the analysis methodologies, analysis tools, assumptions, trade-offs, and results of the contractor's analysis. The rationale for requirements allocation and a traceability matrix depicting the allocation of the requirements herein to respective CI's and CPCI's shall be described in the SRAR. The design data shall reflect the contractor's allocation of the specification requirements defined herein into Configuration Items (CI's).

-439-

- # Computer Program Configuration Items (CPCI's) and required support equipment to be supplied by the contractor under the terms of the contract, inclusive of all interfaces with other equipments or software. Acceptance of the design data by the Government shall not relieve the contractor of the responsibility to meet all of the requirements (explicit or derived) of this specification.

3.13.1.2.1 Hardware design data.- During the design and development cycle the contractor shall design, develop, fabricate, integrate and test and document all hardware [hereinafter referred to as Configuration Items (CI's)] to satisfy the requirements specified herein. The contractor shall prepare and submit the following CI documentation in accordance with the contract schedule and as defined herein.

3.13.1.2.1.1 Prime item development specification/critical item development specification.- The contractor shall perform a system requirements analysis resulting in the allocation of system requirements to Configuration Items (CI's). As a result of the allocation process the contractor shall develop and prepare for each CI a Prime Item Development Specification (PIDS) in accordance with the requirements of MIL-STD-490, appendix II and Data Item Description DID-DI-E-3102, and a Critical Item Development Specification (CIDS) for each critical item within a CI and for each item of deliverable support equipment, in accordance with the requirements of MIL-STD-490, appendix III and DID DI-E-3102. These documents shall be submitted to the Government for authentication in accordance with the contract schedule. On authentication these documents shall form the allocated configuration identification (ACI) for hardware and shall establish the Mode S hardware allocated baseline (reference 3.16.1.2). Subsequent to authentication, the PIDS and CIDS shall be subject to formal configuration control and shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.2.1.2 Prime item product fabrication specification/critical item product fabrication specification.- The contractor shall develop and prepare a Prime Item Product Fabrication Specification (PIPFS) for each CI in accordance with the requirements of MIL-STD-490, appendix VIII and DID-DI-E-3103, and a Critical Item Product Fabrication Specification (CIPFS) for each critical item within a CI and for each item of deliverable support equipment in accordance with the requirements of MIL-STD-490, appendix X and DID-DI-E-30132. These documents shall be submitted to the Government for authentication in accordance with the contract schedule. On authentication these documents shall form the product configuration identification (PCI) for hardware and shall establish the Mode S hardware product baseline (reference 3.16.1.3). Subsequent to authentication, the PIPFS and CIPFS shall be subject to formal configuration control and shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

#

3.13.1.2.2 Not used

3.13.1.2.3 Not used

3.13.1.2.4 Not used

3.13.1.2.5 Computer programs.- During the design & development cycle the contractor shall design, develop and/or acquire, code, integrate and test, implement and document all of the software and/or firmware necessary to satisfy the requirements specified herein. The software shall be developed using a structured thoroughly documented top-down design approach. The contractor shall prepare and submit the following computer program documentation in accordance with the contract schedule and as further defined herein.

3.13.1.2.5.1 Software development plan (SDP).- The contractor shall prepare a SDP in accordance with the Mode S Software Acquisition Documentation Requirements, DOT/FAA/PM-83/37, Part 11, and submit same to the Government for review, comment and final approval in accordance with the contract schedule. On approval by the Government, the contractor shall initiate implementation of the plan and shall maintain and update the plan as required throughout the contract life cycle. The plan shall apply, but not be limited, to the design, development, code, integration and test, implementation and documentation of all software throughout the MODE S contract life cycle. The contractor shall impose SDP requirements in subcontracts consistent with those specified herein to the extent necessary to ensure consistency in software development approaches, methodology and standards between the contractors and subcontractors. The plan shall identify a single focal point of management responsibility for accomplishment of the overall software development activities. Government approval of the SDP shall establish the SDP as a contractual document and shall obligate the contractor to accomplish software development in strict compliance with the SDP, however it shall not relieve the contractor from complying with any/or all requirements of this specification. (The Government will use the SDP to assess the contractor's approach and methods for software development. It will be used as the basis for monitoring and evaluating the development performance and progress).

3.13.1.2.5.2 Functional requirements document (FRD).- The contractor shall prepare a FRD in accordance with DOT/FAA/PM-83/37, Part 1, and shall submit same to the Government for authentication in accordance with the contract schedule. The FRD shall document and allocate each functional performance requirement applicable to the software to specific Computer Program Configuration Items (CPCIs). It shall also provide complete traceability of all software requirements (explicit or derived) from this specification to each of the CPCIs comprising the software for the MODE S System. On authentication, the FRD shall form the initial software Allocated Configuration Identification (ACI) and shall establish the initial MODE S software allocated baseline (reference 3.16.1.2). Subsequent to authentication the FRD shall be subject to formal configuration control and shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

-441-

3.13.1.2.5.3 Software top level design document (STLDD).- The contractor shall prepare a STLDD in accordance with DOT/FAA/PM-83/37, Part 2, for each CPCI defined in the FRD and shall submit same to Government for authentication in accordance with the contract schedule. On authentication, the STLDD's shall form the final software ACI and shall establish the final Mode S software allocated baseline (reference 3.16.1.2). Subsequent to authentication, the STLDD shall be subject to formal configuration control and shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.2.5.4 Software detail design document (SDDD).- The contractor shall prepare a SDDD in accordance with DOT/FAA/PM-83/37, Part 3, for each CPCI documented by a STLDD. The initial "as designed", SDDD shall be submitted to the Government for review and approval in accordance with the contract schedule. This initial SDDD shall form the software development baseline (DOT/FAA/PM-83/37, Part 3). A final, "as built" SDDD shall be prepared and submitted to the Government for authentication in accordance with the contract schedule. On authentication, the SDDD's shall form the software Product Configuration Identification (PCI) and shall establish the MODE S software product baseline (reference 3.16.1.3). Subsequent to authentication, the SDDD shall be subject to formal configuration control and shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.2.5.5 Software test plan (STP).- The contractor shall prepare a STP in accordance with DOT/FAA/PM-83/37, Part 4, for each CPCI documented by the STLDD and SDDD and shall submit same to the Government for review and approval in accordance with the contract schedule. On approval, the final version STP shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.2.5.6 Software test procedures (STPr).- The contractor shall prepare software test procedures in accordance with DOT/FAA/PM-83/37, Part 5, for each CPCI for which a STP has been prepared and shall submit same to the Government for approval in accordance with the contract schedule. On approval, the final version software test procedures shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.2.5.7 Software test report (STR).- On completion of the qualification testing phase for each CPCI (reference 4.4.2) the contractor shall prepare a STR in accordance with DOT/FAA/PM-83/37, Part 6, and submit same to the Government for review and approval in accordance with the contract schedule.

3.13.1.2.6 Not used

3.13.1.2.7 Not used

3.13.1.2.8 Not used

3.13.1.3 System qualification & acceptance test plans.- The contractor shall develop and prepare and submit a single system test plan in accordance with JID DI-T-3701 (excluding paragraph 7, Item f) which outlines the complete #

- # testing program to demonstrate compliance of the sensor equipment with the requirements of this specification. The system test plan shall be submitted to the Government for review, comment and approval in accordance with the contract schedule. On approval the final version system test plan shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2. The plan shall provide an overview of all proposed test activities for each configuration item (CI) and computer program configuration item (CPCI) for the first unit of each CI and/or CPCI as well as for all subsequent production units. Automatic test equipment (ATE) and procedures may be used provided that all requirements herein are satisfied. The system test plan shall provide for separate and distinct test classifications, conforming to the tests specified below, and including those specified in section 4 herein and paragraphs 4.3 and related subparagraphs of FAA-G-2100. #

(a) Contractor's preliminary tests

(b) Design qualification tests

(1) General characteristics tests

(2) Environmental tests

(3) Reliability test and demonstration.- The reliability test plan shall be separately bound but otherwise a part of and referenced in the overview test plan.

(4) Maintainability test.- The maintainability test plan shall be separately bound but otherwise a part of and referenced in the overview test plan.

(c) Type tests

(1) Performance tests.- The performance tests shall demonstrate that the equipment fully satisfies the detailed performance requirements specified herein.

(2) Production reliability verification tests.- The production reliability verification tests shall be conducted in accordance with the reliability test plan's requirements for verification of the reliability of production equipment.

(3) Temperature and humidity tests.- The equipment shall be tested to insure its operation over the temperature and humidity service conditions (3.11.1.2).

-441b-

- (d) Production tests.- The production or factory acceptance tests shall be similar to the performance type test but shall be conducted at a higher (e.g., module and system) level. It shall verify that the major requirements of the performance type test are being consistently met.
- (e) On-site tests.- The on-site or "final sell-off" tests shall be similar to the production tests except that the reliability tests shall not be repeated. In addition, the test shall demonstrate the correct operation of the Mode S sensor with its associated radar and data communication equipment.

3.13.1.3.1 Acceptance test procedures (ATP's).- The contractor shall develop and prepare an ATP for each CI, critical item, and item of deliverable support equipment documented by a PIPFS and/or CIPFS in accordance with DID DI-T-3714, and submit same to the Government for approval in accordance with the contract schedule. On approval, the final version ATP shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.13.1.3.2 Acceptance test reports.- On completion of the testing required by the applicable ATP, the contractor shall prepare an acceptance test report (ATR) in accordance with DID DI-T-3718 and submit same to the Government for review and approval in accordance with the contract schedule.

3.13.1.3.3 Reliability test plan.- An integrated reliability test and demonstration plan shall be prepared in accordance with paragraphs 5.3.1 and 5.3.3 of MIL-STD-785 and the requirements of the reliability program plan as provided by 3.13.2.1.1 herein. The plan shall provide specific and detailed test objectives and a thorough discussion of the techniques and methods which are to be used to meet these objectives and the testing requirements of 4.3.3.3 and 4.3.4.2 herein.

This space intentionally unused.

3.13.1.3.2 Maintainability test plan.- The contractor shall prepare a maintainability demonstration test plan in accordance with paragraph 5.11 of MIL-STD-470, paragraph 4.2 of MIL-STD-471, and the requirements herein. The plan shall provide specific test objectives and a thorough discussion of the methods to be used to meet these objectives and the testing requirements of 4.3.3.4 herein.

3.13.1.4 Not used

3.13.1.5 Not used

3.13.1.6 Site preparation reports.- The contractor shall submit a site preparation report for each site receiving Mode S equipment. Where the requirements of the installations are identical, a single report may apply to multiple sites. The site preparation report will be used by the Government to prepare the site for installation of the contractor's equipment and to perform necessary services not required of the contractor. Therefore, all requirements to prepare the site for installation of the equipment shall be included. The report shall include but not be limited to the following:

- (a) Typical floor plan layouts of Mode S operational and maintenance equipment and spares.
- (b) List of the Mode S equipment and tools to be delivered to site by the contractor.
- (c) Tabulation of the mechanical and electrical characteristics of each piece of equipment. Included shall be the definition of power requirements, circuit breaker panels, heat load in BTU per hour, starting surge current data, circuit breaker requirements, and power factors. The overall dimensions and weights (crated and uncrated) and any other information needed for the Government to prepare for the equipment installation shall be provided.
- (d) Definition of cable and connector requirements for the complete installation, including typical cable access points and routing.
- (e) Definition of any office equipment and space required by the contractor during the installation and checkout period.
- (f) Identification of requirements for Government and other contractor's services and test equipment, if any.
- (g) List of temporary test equipment, if any, which will be supplied by the contractor.
- (h) A tabulation of typical or estimated work schedules, requirements and plans.

- (1) Sensor remote CPME site requirements, including such items as number of sites to be installed, site location criteria; site equipment, layouts, services required, and antenna tower installation requirements.

3.13.1.7 Installation documents.- The contractor shall submit installation documents for each site to the Contracting Officer for approval. The documents shall contain all necessary information required by trained technicians and engineers to correctly install the equipment and initiate its operation. Included shall be step-by-step procedures for off-loading, unpacking, and placing the Mode S sensor and its supporting equipment. Detailed and understandable checkout procedures of a depth similar to those which would be used by contractor personnel if installation is required by the contract shall be provided. In summary, all activity relating to the installation effort, starting with the arrival of the first piece of equipment, material or personnel to the presentation of the equipment for integration testing shall be fully described. Section 3.6.18 and related subsections of FAA-D-2494 shall be used as a guide to the type of information required. For each site, all "site adaptable" parameters, including the coverage map described in section 3.4.8 shall be provided by the contractor.

3.13.1.8 As-built installation drawings.- Site installation drawings covering all equipment installed and in place for each Mode S system shall be provided for each site at which contractor installation is required by the contract schedule. The drawings shall include power distribution cabling, signal and control cables, lightning surge protection system, ground systems, floor plans, and equipment identification as a minimum. The drawings shall be prepared in accordance with FAA-STD-002.

3.13.1.9 Interface control documents.- The contractor shall submit for Government approval all interface control documents specified below. The level of detail shall be sufficient to completely describe all electrical/electronic, mechanical/physical, protocol/formats, and/or software required for interfacing the Mode S sensor.

The contractor shall provide the following interface control documents:

- (a) Mode S/ATC Communications link
- (b) Mode S/non-ATC Communications link
- (c) Mode S to ASR-7/ARTS-2A Terminal Sites
- (d) Mode S to ASR-8/ARTS-2A Terminal Sites
- (e) Mode S to RMMS
- (f) Mode S to Common Digitizer (Model-2), as colocated at the following radar sites:
 - ARSR-1
 - ARSR-2
 - FPS-20
 - FPS-66
 - FPS-67
- (g) Mode S/ATC Surveillance Link to ATC Enroute Facilities
- (h) Mode S RMS to local (portable) terminal

3.13.1.10. Integration test procedures.- The contractor shall prepare detailed test procedures which provide assurance that the installed

operational Mode S equipment is correctly interfaced with its associated radar and data transmission equipment. The tests shall verify the timing, alignment, and other internal Mode S sensor adjustments required to adapt the sensor to its associated equipment. The accuracy of the Mode S sensor data output, and its correct functioning shall be demonstrated. Once approved by the Government, these procedures shall be used for the integration tests specified in section 4.3.8 herein.

3.13.1.11 Electromagnetic interference control plan.- The contractor shall prepare and submit an electromagnetic interference control plan detailing the contractor's plans and methods to be used to satisfy the requirements of MIL-STD-461 for Class A3 equipment and subsystems. Once approved by the Government, the plan, together with and subject to this specification, shall be binding on the contractor.

3.13.1.12 Quality control system plan.- The contractor shall prepare and submit a quality control system plan in accordance with paragraph 3.1 and associated subparagraphs of FAA-STD-016 and FAA-STD-018, except that those elements which are redundant with the instruction book manuscript plan (3.13.2.2) need not be repeated in the quality control system plan.

3.13.2 Hardware documentation.- The following subparagraphs specify the documentation requirements for the Mode S sensor hardware.

3.13.2.1 Reliability and maintainability documentation.- The contractor shall document and provide the results of its reliability and maintainability programs as specified herein.

3.13.2.1.1 Reliability program plan.- The contractor shall prepare a reliability program plan as specified in 3.9.3.1. A preliminary plan shall be submitted with the bidder's proposal as required by the solicitation. Upon approval by the Government, the preliminary plan shall become the basis for a final program plan which shall be submitted as established in the contract schedule.

3.13.2.1.2 Reliability status report.- The contractor shall prepare reliability status reports as specified in 3.9.3.3.10. Additionally, the contractor shall submit with the status reports, the current results of the following reliability program tasks:

- (a) Thermal design analysis (3.9.3.3.2)
- (b) Reliability requirements allocation (3.9.3.3.3)
- (c) Reliability predictions (3.9.3.3.4)
- (d) Total logistic predictions (3.9.3.3.5)
- (e) Failure modes, effects, and criticalness analysis (3.9.3.3.6)
- (f) Failure summaries (3.9.3.3.9)

3.13.2.1.3 Maintainability program plan.- The contractor shall prepare a maintainability program plan as specified in 3.9.4.1. A preliminary plan which includes the preliminary maintenance predictions required by 3.9.4.3.5 shall be submitted with the bidder's proposal as required by the solicitation. Upon approval by the Government, the preliminary plan shall become the basis for a final program plan which shall be submitted as established in the contract schedule.

3.13.2.1.4 Maintainability concept plan.- The contractor shall submit the maintenance concept plan (3.9.4.3.2) to the Government for approval as established in the contract schedule. The approved plan shall be incorporated into the remainder of the maintainability program as established by the approved maintainability program plan.

3.13.2.1.5 Maintainability status report.- The contractor shall prepare maintainability status reports as specified in 3.9.4.3.8. As they become available, the results of the following maintainability program tasks shall be fully presented in the status reports:

- (a) Maintainability design tradeoffs (3.9.4.3.4)
- (b) Maintainability predictions (3.9.4.3.5)

3.13.2.2 Equipment instruction books.- The contractor shall prepare a manuscript plan and the draft and final, reproducible manuscripts for the Mode S equipment instruction books as established in the contract schedule.

The manuscript plan and its schedule shall be prepared in accordance with paragraph 3.2 and its subparagraphs of FAA-D-2494, except that a minimum of three months shall be allowed for Government printing of the instruction books. The plan shall include sample drawings and text of the type proposed for use in the equipment instruction books. The contractor procedures of paragraph 3.13.2.2.9 shall be included in the manuscript plan. Upon approval by the Government, the plan shall, subject to and in conjunction with this specification and contract, be binding on the contractor.

The Mode S sensor instruction book shall include sufficient level of detail on the hardware and software and their interactions to provide a thorough understanding of all Mode S sensor functions. Its organization, content, and level of detail shall be such that Mode S sensor problems, and problems concerning the interfaces with external systems and devices are able to be diagnosed and remedied by maintenance personnel who were trained using the instruction book as a text. Separate, "stand-alone" instruction books shall be provided for the operation, description, maintenance, and repair of the Mode S sensor supporting equipment (3.10.2), less the extenders. The manuscripts for the instruction books shall be prepared in accordance with FAA-D-2494 as modified herein. The use of abbreviations on drawings and in text shall be minimized as much as possible. When used, the abbreviations shall be in accordance with American National Standards Institute (ANSI) Y1.1 (1972).

This space intentionally left blank.

3.13.2.2.1 Manuscript reference designations.- The reference diagrams, symbols, and abbreviations used in the manuscripts shall conform to the requirements of paragraphs 3.4.1 and its subparagraphs of FAA-D-2494 as modified by paragraph 3.11.2.10 herein. Digital logic diagrams shall conform to the requirements of FAA-STD-010 except that American Standards Institute (ANSI) Y32.14 (1973) shall be used in lieu of MIL-STD-806B. The distinctive symbol shapes of Y32.14 shall be used wherever possible. The symbols used shall reflect the actual logical function of the circuitry. Thus, the NAND gate used as a NOR with active low-level input signals, shall be shown as an OR symbol with "bubbled" (active low) inputs. Each discrete logic gate shall be shown on the detailed drawings with all of its input and output signals and their mnemonics. Thus, an inverter driving a NAND gate shall be drawn as such, not as a NAND gate with one inverted (bubbled) input. All mnemonics shall have the same number of characters and each shall indicate whether a logic high or a logic low is the active (true) condition for that signal.

3.13.2.2.2 Not used.-

3.13.2.2.3 General description.- The general description in Section 1 of the instruction books shall be in accordance with the requirements of FAA-D-2494, paragraph 3.6.10.2

3.13.2.2.4 Technical description.- The technical description in Section 2 of the instruction books shall be in accordance with paragraph 3.6.11 and related subparagraphs of FAA-D-2494 as modified and limited herein.

3.13.2.2.4.1 Theory of operation.- The theory of operation of the equipment's hardware shall be presented in at least three levels. The first level shall be a complete and detailed description of the signal flow and information exchange between Mode S sensor modules and between the Mode S sensor equipment and the associated external equipment. This level of theory, in conjunction with the general description of Section 1, shall suffice to completely describe the overall Mode S system, including the major functions of each module, the system-level and module-level data paths and all interconnection details necessary to interface the Mode S sensor to its associated radar equipment.

The second or intermediate level shall describe the major function signal flow and control features for each module. This level shall provide all of the information necessary for "remove and replace" troubleshooting on the system

level and the module level. The third and most detailed level shall contain all of the information necessary for understanding the detail functions of each module and the circuit and logic details at the functional level. All interface receiver and driver circuits, for both intermodule and external signals, shall be thoroughly described to the individual component level. The operation of all ROM controller circuits, if used, must be completely described including such data as state diagrams, flow charts, and ROM chip program listings (data vs. address).

New or unusual circuits shall be described thoroughly and in detail. Descriptions shall be technically precise and shall use discrete, well-defined conditions and states. Generalities and vague or misleading statements shall be avoided. Specific logic conditions and levels shall be used when describing a logic operation or permissible states. Binary counters, parallel-to-serial registers, logic gates, adders, and other standard logic circuit functions need not be described in detail. Descriptions of the microprocessor chips, memory chips and all other large-scale-integration digital and linear circuits shall be limited to functions, and Inputs/Outputs. Internal operation of these items shall not be included.

The depth of the theory shall be sufficient to describe the functions and operation of each individual circuit and its relationship to the module or assembly of which it is a part. The text shall be supported by appropriate illustrations, photographs, and diagrams. The text and its associated figures shall always agree in both the level of complexity and the technical contents. The diagrams shall reflect the configuration described in the text and shall not contain references to deleted parts or functions to be added, unless the added functions are an inherent part of the equipment's design (e.g., addition of the Military interface group). The text shall refer to signals by the name with which they are identified on the associated drawing. For example, if a diagram shows signal XYZ as the reset input to U4B, then the text must also mention xyz when describing the operation of U4B. It is not sufficient to merely say "...the reset into U4B. . .".

3.13.2.2.4.2 Technical illustrations.- The technical illustrations used in the instruction books shall be clear, technically accurate and, where supporting a portion of text, of a complexity appropriate for the text's level of detail. The illustrations shall be equivalent in technical content and scope to the example figures in FAA-D-2494. Special symbols shall be kept to an absolute minimum; normal electronic component and logic symbols (3.13.2.2.1) shall be used to the greatest extent possible. The cited example figures are intended to convey a sense of the desired form and coverage. The precise format details shown in the examples need not be followed, provided that the technical content and depth of coverage are not compromised. Photographs and other illustrations shall be included as necessary to support and complete the technical descriptions. To the extent possible, consistent with keeping the sizes of the volumes manageable, the illustrations which support the general description and levels one and two theory descriptions shall be included with the text.

They may be specific or general block diagrams of functional elements, as appropriate. The detailed drawings which support the level three theory and troubleshooting sections shall be bound in a separate volume to facilitate handling and analysis of the information. A detailed set of technical drawings which show the wire-by-wire interconnections for the complete equipment shall be provided. Specific requirements for the technical illustrations are presented in the following subparagraphs:

(a) The term "device" in paragraph 3.6.20.7 of FAA-D-2494 shall include CCAs and other plug-in or wired-in assemblies, or units of similar complexities.

(b) Logic circuit diagrams shall show the multiple circuits or functions of integrated circuits and similar devices as separate logic blocks or components in lieu of the one-for-one relationship specified in paragraph 3.6.11.2.3(a) of FAA-D-2494. The multiple blocks shall be distinguished with letter suffixes to facilitate identification (e.g., U2A, U2B, etc.). In the event that the functions of a logic chip are split such that, for example, three bits of a four-bit-wide memory chip are used in one function and the remaining bit is spare or is used elsewhere, the logic diagram representations of each part of the chip shall indicate which part of the chip (which bits, in this example) are used in each function.

(c) All multi-sheet logic and schematic diagrams shall have sheet-to-sheet mapping which permits signal tracing in both directions. All lines entering or leaving a diagram must have mnemonics or other signal names and all appropriate source or destination sheet numbers. Signals leaving or entering via connectors, jacks, or plugs must have the connector, jack, and plug reference designations, pin numbers and cable numbers as applicable. An indication of the direction of the information flow shall be provided for each entering or exiting signal. The indicators shall be near the edge of the diagram and shall be independent of any connector symbology. All third-level diagrams shall have alphanumeric zone coordinates consisting of equally-spaced alphabetical divisions along the left-hand border and equally-spaced numerical divisions along the top border. The signal mapping shall use the zone references, and the associated theory text shall include the zone references at the first mention of a signal, circuit, or component.

(d) All components shown on simplified or intermediate diagrams shall be identified by reference designations to permit ready reference to the same components on the associated detailed diagrams. Signal names shall also be cross-referenced for the same reason. The detailed logic and schematic diagrams shall include complete and specific reference designations for each component. Each component shall be identified by a value or a part number (e.g., 400K, SN404, etc.) as applicable. Large-scale integrated circuit chips shall be identified by function (RAM, CPU, adder, etc.). Each

component in a detailed diagram shall have all of its signal pin connections shown, even those that are grounded or not used, and all signal lines shall be fully identified. The detailed logic diagrams shall not be annotated with verb-noun statements as specified in paragraph 3.6.11.2.3(d) of FAA-D-2494.

(e) Complex self-test circuits shall be shown as separate functions on separate diagrams.

(f) The schematic diagram or logic diagram or both for a CCA or other plug-in assembly shall be shown on a page or pages immediately preceding the circuit board (baseboard) illustrations.

(g) Wiring diagrams and lists shall show all cables, wiring, conductors, connectors, plugs, jacks, sockets, and pins, in addition to the information required by paragraph 3.6.20.19 of FAA-D-2494.

(h) Each functional entity such as an amplifier stage, a logic comparator, a memory, etc., shall be identified by an appropriate functional stage name. The name shall be written in full or abbreviated. Single components shall be identified by their reference designations.

(i) In lieu of the requirements of paragraph 3.6.20.9 of FAA-D-2494, the drawings shall be identified as specified herein. All detailed drawings which show a portion of more than one CCA or similar physically-partitioned assembly of the same or greater approximate complexity shall use dashed outlines to clearly show the physical boundaries of such assemblies. Thus, components on plug-in assembly shall be enclosed by a dashed outline to distinguish the assembly from the next higher assembly or module. Each hardware assembly or portion thereof which is shown on a diagram, even if not shown in conjunction with other levels, shall be identified by official nomenclature (FAA type number), if applicable, and by reference designation and the manufacturer's assembly or part number. These requirements also apply to modules, cabinets and similar items in higher-level diagrams, although the dashed lines are not required if the required delineation of units can be clearly presented without them.

(j) The use of equivalent circuits, as permitted by paragraph 3.6.11.2.1 of FAA-D-2494, shall be subject to individual approval by the Government during the review of the manuscript.

(k) In lieu of the requirements of paragraph 3.6.20.7.1 of FAA-D-2494, individual components within analog or linear integrated circuits need not be shown on the maintenance diagrams, provided that sufficient information is presented to permit adequate troubleshooting and provided that the chip's circuit diagram is available elsewhere within the instruction book.

(1) Notes shall be provided on each diagram as necessary to explain conditions shown, to clarify special symbol or signal conventions or to identify differences between equipment configurations.

(m) X-ray type views of wiring connections for all printed circuit type boards used shall be provided. For all wire wrap assemblies of any type, tabular wiring string sequential connection data shall be provided, indexed by mnemonic signal label, indicating successive string connection points, with special notation for signal source connection within string.

3.13.2.2.5 Fault isolation procedures. Paragraph 3.6.16.2 of FAA-D-2494 is modified to require the isolation methods and procedures to be in accordance with the approved maintenance concept and maintenance program plan. The procedures shall enable fault isolation to the lowest possible and practical replaceable or repairable item. Automatic test equipment and procedures shall be used as much as possible. The procedures shall also be structured to minimize the system out-of-service time.

3.13.2.2.6 Installation, integration and checkout. The instruction book shall not contain the information required in paragraph 3.6.18 and related subparagraphs of FAA-D-2494 since the information is to be provided in the installation documents and as-built drawings required in 3.13.1.7 and 3.13.1.8 herein. Section 9.0 of the instruction book shall contain suitable cross-references to these separate documents.

3.13.2.2.7 Computer software. The instruction book shall not contain the information required in paragraph 3.6.19 and related subparagraphs of FAA-D-2494 because the information is to be provided in the software documentation furnished in accordance with 3.13.3 herein. Section 11.0 of the instruction book shall contain suitable cross-references to this separate documentation.

3.13.2.2.8 Foldouts. The use of foldouts shall be kept to a minimum consistent with clear and complete presentation of the required material. Each foldout shall be able to be easily extended and refolded with its free edge to the outside edge of the document. In the folded position, all page numbers, document numbers (e.g., TI-4234), figure numbers, and titles shall be visible for both the left-hand and the right-hand printed pages.

3.13.2.2.9 Contractor procedures. The contractor shall develop, issue, maintain, and distribute written procedures for preparation and inspection of manuscripts. The procedures shall be written in a manner that will assure compliance with FAA-D-2494, as modified herein. Copies of contractor procedures shall be made available to the FAA on request.

3.13.2.3 Drawings and technical memoranda. The contractor shall maintain an index of all drawings and technical memoranda produced in connection with design, fabrication, and test of the equipment. This index shall be updated and copies provided to the Government with the management reports (3.13.1.1). All lined pencil work and lettering shall be of such quality that it can be clearly reproduced to at least a second-generation copy. All drawings submitted by the contractor on FAA formats shall meet the requirements of FAA-STD-002. The

contractor shall provide drawings or technical memoranda that may be requested by the Contracting Officer as listed in any index furnished in accordance with this requirement.

3.13.2.4 Provisioning technical documentation.- Provisioning documentation shall be supplied in accordance with FAA-G-1210 as established in the contract schedule. The list of standard test equipment (3.10.1) shall indicate the make and model of each item and the salient technical characteristics that make it a necessary piece of Mode S sensor maintenance equipment. The list shall be prepared in accordance with paragraphs 3.13.1 and 3.13.2 of FAA-G-1210.

3.13.2.5 Operator's manuals.- The contractor shall prepare and deliver separate operator's manuals as needed, including manuals for the sensor hardware, the CPME (appendix VIII; when required by the contract schedule), the ARIES simulator (appendix IX; when required by the contract schedule) the CCA test set (3.10.2.1), and the Support Facilities (appendix II). Each manual shall provide a thorough description of the uses of the equipment. The manual shall clearly indicate its relationship to other program documentation, describe the function of all operator controls, describe the use of all peripheral equipment, and provide detailed operating procedures.

3.13.3 Software documentation.- The contractor shall deliver all documentation necessary for Government personnel to maintain and modify all deliverable Mode S sensor computer programs. The contractor shall adhere to the requirements of DOT/FAA/PM-83/37 to document the deliverable software for the Mode S sensor. The documentation listed in DOT/FAA/PM-83/37 shall be deliverable items as required in the contract schedule. Commercial documentation may be part of, or referenced in the delivered documentation only upon written Government approval.

3.13.3.1 Version description document (VDD).- The contractor shall prepare a VDD for each CPCI in accordance with DOT/FAA/PM-83/37 Part 7. The VDD shall accompany the shipment of each CPCI to the Government. The contractor shall implement and maintain a system that ensures each CPCI change approved by the Government is accounted for and the delta differences between any CPCI version delivered subsequent to initial CPCI delivery are described.

3.13.3.2 Software user's manual.- The contractor shall prepare a Software Users Manual in accordance with DOT/FAA/PM-83/37, Part 8, for each CPCI developed by the contractor. The contractor shall validate the software users manuals in accordance with FAA-D-2494 and submit same to the Government for approval in accordance with the contract schedule. Commercial user's manuals provided with CPCIs procured by the contractor as off-the-shelf items may be submitted to the Government for approval in lieu of the manuals specified herein, provided the manuals are sufficient to ensure proper use of the respective CPCIs by contractor and Government software development/maintenance personnel.

3.13.3.3 Software maintenance manual.- The contractor shall prepare a software maintenance manual in accordance with DOT/FAA/PM-83/37, Part 9. The contractor shall validate the software maintenance manual in accordance with FAA-D-2494 and submit same to the Government for approval in accordance with the contract schedule.

3.13.3.4 Diagnostics manual.- The contractor shall prepare a diagnostics manual in accordance with DOT/FAA/PM-83/37, Part 10. The contractor shall validate the diagnostics manual in accordance with FAA-D-2494 and shall submit same to the Government for approval in accordance with the contract schedule.

3.13.4 Configuration management plan.- The contractor shall prepare a Configuration Management Plan as specified in 3.16.1. In addition the plan shall describe the contractor's Data Management system: procedures for management, control, and accountability of all data; audit procedures; and subcontractors/vendor control procedures.

This space intentionally unused

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-4

-453-

This page intentionally unused.

3.13.5 Life cycle cost documentation.-

3.13.5.1 Life cycle cost model description.- The contractor shall submit a description of the LCC model to the Government for review and approval. This description shall include but not be limited to a description and status of the model, rationale for selection, contractor and Government input data, data validation procedures, model outputs, principal analytical formula, algorithms and constants.

3.13.5.2 Life cycle cost analysis reports.- The contractor shall submit LCC analysis reports documenting his life cycle cost considerations including a description of the LCC analysis options considered and quantitative results of the analysis.

3.13.5.3 Life cycle cost estimation reports.- The contractor shall submit a Mode S 20-year total LCC estimation report including the cost of all recurring and non-recurring elements described in the approved LCC model description.

#

This space intentionally unused.

-455-

- # 3.14 Spare parts.- As established in the contract schedule, the contractor shall provide spare parts in accordance with the following subparagraphs. A provisioning conference may result in modification to the requirements herein.

3.14.1 CMF spares.- The contractor shall supply a set of CMF spares with the delivery of every six sensor sites beginning with the sensor site one and continuing with every sixth site thereafter (i.e., 1, 7, 13, . . .) until the quantity required by the contract schedule has been delivered. A set of CMF spares shall consist of a quantity of each Lowest Replaceable Unit (LRU) at the sensor site including each circuit card assembly (whether wired-in or plugged-in) and each plug-in assembly (such as a power regulator, analog-to-digital converter, test probe, display assembly, or similar unit). If a given LRU has multiple uses that are changed by inserting PROMs or similar devices which alter the computer program used by the LRU, spare PROM's or similar devices may be provided as CMF spares in lieu of multiple LRU's with PROM's already inserted. The spare PROM's or similar devices shall be programmed and capable of immediate operation in the appropriate Mode S sensor equipment. For logistical support purposes, all PROMs containing different internal data sets (programs) shall be treated as separate and individual parts even if they are identified by the same vendor part number (e.g., 2708). Standard or common parts, including cathode ray tubes, LED display pannels, keyboards and the like, are specifically excluded from the CMF spares package. Included in the CMF spares package shall be quantities of all LRUs defined as parts-peculiar as defined in paragraph 3.2 of FAA-G-1375b except that cable assemblies, wiring, meters, hardware, card bins, gears, and similar items are added to the list of the parts excluded in the definition.

The quantity of spares provided for each LRU in a set of CMF spares shall represent the pipeline spares required for an average CMF servicing 6.85 sensor sites and shall be determined by the product of the LRU failure rate, (expressed as failures per 24-hour day), the number of LRU applications per sensor site, an average 6.85 sensor sites per CMF spare set, and a mean CMF turn around time of 20 days. When the calculation results in a fractional number, the quantity provided shall be the next highest integer; in no case, however, shall the quantity of any LRU in a set of CMF spares be less than one.

When the system design requires the replacement of any part subassembly, or assembly not included in the above categories in order to meet the maintainability requirements herein (3.9.2), such items shall be considered to be peculiar parts for provisioning purposes.

The CMF spares shall be delivered as required by the contract schedule.

3.14.2 Depot Spares.- The contractor shall provide quantities of peculiar parts, including both LRU's and LRU repair parts (piece parts), as Depot level spares as established in the contract schedule. Included in the Depot spares package shall be quantities of all replaceable parts and assemblies which are unique to the Mode S sensor. These items shall be parts peculiar as defined in paragraph 3.2 of FAA-G-1375b except that cable assemblies, wiring, meters, hardware, card bins, gears, and similar items are added to the list of parts which are excluded in the definition. The quantities #

- ‡ provided shall be determined for two categories of peculiar parts: 1) those for which a complete reprourement package is provided including all necessary specifications, drawings, data rights, and other technical documentation to facilitate a competitive procurement; and 2) those for which a complete reprourement package is not provided.

The quantities provided for each peculiar part with a complete reprourement package shall represent the pipeline spares required for M depots (M=1) servicing S/M sensor sites (S=78 for basic program, S=137 for basic program + option) and shall be determined by the product of each peculiar part failure rate (expressed as failures per 24-hour day), the number of peculiar part applications per sensor site, and a mean depot repair turn around time of N days (N=40). The nominal values of M, S, and N may be altered in the contract schedule. When the calculation results in a fractional number, the quantity provided shall be the next highest integer; in no case, however, shall be quantity of depot spares for any peculiar part with complete reprocrement package be less than one.

The quantities provided for M depot (M=1) of each peculiar part without a complete reprourement package shall represent a 20-year system lifetime requirement, and shall be determined by the product of each peculiar part failure rate (expressed as failures per 24-hour day), the number of peculiar part applications per sensor site, S/M sensor sites (S=78 for basic program, S=137 for basic program + option), 365 days per year, a 20-year life, and a condemnation rate determined through maintainability analysis by the contractor, but not to exceed 5 percent of total repair per year for repairable parts. The nominal value of S and M may be altered in the contract schedule. When the calculation results in a fractional number, the quantity provided shall be the next highest integer; in no case, however, shall the quantity of depot spares for any peculiar part without complete reprourement package be less than one.

3.14.3 Sensor support facility spares.- The contractor shall provide quantities of peculiar part LRU's for the Support Facilities (Appendix II) as defined in paragraph 3.2 of FAA-G-1375 except that cable assemblies, wiring, meters, hardware, card bins, gears, and similar items are added to the list of the parts excluded in the definition. These peculiar part LRU's shall include any specially designed controller or other equipment fabricated especially for the Mode 3 Support Facilities application. Commercially available equipment used for the Support Facilities function, as defined in paragraph 3.1.6 of FAA-G-1375, is excluded from the Support Facilities spares requirement.

The quantity provided for Support Facilities spares shall be calculated in a manner consistent with paragraph 3.14.2 except that S (S=3) Support Facilities sites should be used in the calculation and one depot (M) site. The nominal value of S can be changed in the contract schedule.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-5

-455b-

This page intentionally unused

FAA-E-2716

-456-

This page intentionally unused.

3.15 Installation and checkout.

3.15.1 Air traffic control operating constraints.- When the installation and testing of equipment is performed in an operating environment, ATC activities and services shall have a priority over all contractor activities. There shall be no compromise in the safe and timely control of aircraft during these phases. The design of installation and testing procedures shall be based on continued use of existing navigational aids. Installation services shall be performed in such a manner that disruptions to operating ATC facilities shall be minimized. Contractor actions that will interfere with or in any way have an impact on ATC activities and services shall be coordinated with and approved by the contracting officer or his designated representative in advance. The installation plan (3.15.3.1.1) which shall be furnished by the contractor, shall detail a proposed procedure for minimal interruption of radar service while the contractor is installing, testing, and integrating the Mode S equipment. The installation plan shall assume that any work requiring shut-down of the operating ATC and/or sensor system shall be accomplished during the hours of 10:00 p.m. until 6:00 a.m. based on Government approval.

3.15.2 Equipment and services to be furnished.

3.15.2.1 Equipment and services to be provided by the contractor.- The contractor shall provide the services and materials necessary to install, align, test, and integrate the Mode S sensor as required by this specification. These activities shall occur at those sites and at the times specified by the contract. The work to be performed shall include installation and checkout of existing GFE as a part of the overall contractor system installation, integration and checkout efforts. The work shall also include equipment unit and subsystem interconnections, testing and demonstration of the ability of the integrated system to meet specified system performance requirements. The work shall be planned so as to assure efficient integration with existing sensors and ATC facilities. On-site work shall be scheduled and conducted so as to impose negligible impact on ongoing operational activities. In addition, the contractor shall provide all necessary services and material to prepare, reproduce, and provide reports, computer programs and documentation as necessary to successfully complete the installation and integration effort. Any feature or item necessary for performing this task in accordance with the requirements of the contract shall be incorporated even though that item or feature may not be specifically described herein. The contractor shall provide logistic support for GFE.

3.15.2.1.1 Major contractor furnished services and equipment.- All equipment and services shall be delivered and installed at the locations specified by the Government. All facilities, parts and hardware including system/subsystem grounding plates, receptacles, connectors, cabling, wiring, adapters, and outlets, except GFE facilities specified in 3.15.2.2, shall be provided to enable the components of each system to be assembled, interconnected and installed as required by these specifications. The major items of equipment

and services to be furnished are:

- a. Software required for system checkout, test and integration.
- b. Module and system testing, as specified herein.
- c. Special tools, system monitors, simulators, alignment, and test equipment, not supplied as GFE and required for the tasks specified herein.
- d. Cables, cable runs, bridging and isolation equipment, conduit and/or other cable supports necessary for interconnecting Mode S sensor equipment to the other systems located at the Mode S sensor site except for the Government furnished cables specified in 3.15.2.2.
- e. Required power cables and ac power duct, conduit, or other appropriate cable support between the Mode S equipment cabinets and the Mode S power panel.
- f. Installation, test and integration documentation as specified herein.
- g. Inspection of site preparation work prior to shipment of equipment.
- h. Temporary RF switches to permit switching between the Mode S sensor antenna interface and the ATCBI/antenna interface, as needed to accomplish the installation, site acceptance, integration and commissioning of the Mode S sensor.
- i. An RMS with Mode S application software (part of RMS described in 3.4.10.6) at all installation sites. RMS application software is required at all sites.
- j. CPME specified in Appendix VIII as required by the contract schedule.
- k. ARIES specified in Appendix IX as required by the contract schedule.
- l. Mode S SSF and Mode S F3F specified in Appendix II as required by the contract schedule.

3.15.2.2 Government furnished equipment (GFE) and services.- The Government will provide or install, or both, where applicable.

- a. All existing equipment at ATC/NAS facilities needed to accomplish integration.
- b. Appropriate space at the ATC facility or equivalent to accommodate contractor engineers during the installation and integration period. This will include desks, chairs, typewriters, filing cabinets and telephones.
- c. Appropriate cable, cable runs, and supports between the contractor-provided wall mounted interconnection junction boxes and

-459-

the following NAS equipment interfaces:

- (1) Airport surveillance radar (ASR-9)(3.5.2.4)
 - (2) NAS facilities interface and communications link (3.5.3) #
- d. All grounding wires to appropriately tie together the Mode S sensor grounding system and the grounding system within the ATC facility as specified in FAA-STD-019. The grounding system shall be installed in accordance with the Mode S sensor data supplied by the contractor in the Government-approved installation plan.
 - e. Drawings of the radar site and ATC facilities and interface data for those facilities necessary for development of the installation plan.
 - f. Not used.
 - g. Any test equipment, monitors or simulators not supplied by the contractor but deemed necessary for routine maintenance of the system, as mutually agreed to by the Government and the contractor.
 - h. Necessary, space, power, lighting, heating and air conditioning, including power panels, grounding and cable supports at the PSF and Mode S SSF to be installed at those locations stipulated in the contract schedule (3.15.3.1.1.15).
 - i. Modems to implement interfaces with other facilities as specified in 3.4.10, 3.5.2 and elsewhere in this document (including modems needed at existing ATC/NAS Facilities) in accordance with the contract schedule. The government shall also provide all cables needed between the Mode S sensor and those modems located at the Mode S site, and between other systems or equipment and those modems to be located at existing facilities.
 - j. Interconnecting telephone lines to interface the Mode S sensor and other facilities as specified in 3.4.10, 3.5.3, and elsewhere in this document.
 - k. (Not used.)
 - l. Sites suitable for installation of CPME based on the contractor's documented requirements.
 - m. Technical data and drawings required to permit the contractor to fabricate or purchase cables needed between other systems or equipment to be located at existing facilities (3.15.2.1.1, item d.).
 - n. Mode S site coordinates to the required accuracy for proper operation of the sensor.
 - # p. Appropriate cable, cable runs, and supports between the contractor-provided ARIES connectors and the ARIES equipment for both the R.F. and digital sensor to ARIES interfaces. #

3.15.3 Documentation.

3.15.3.1 Installation documents.- As per 3.13.1.7.

3.15.3.1.1 Installation plan.- A Mode S sensor installation plan shall be furnished by the contractor for Government approval for each site receiving Mode S equipment. The information contained in the plan will be used by FAA field organizations and facilities to prepare each site for system delivery, and follow-on installation and checkout activities. Where the requirements of the installation are identical, a single report may apply to multiple sites. The site preparation report will be used by the Government to prepare the site for installation of the contractor's equipment and to perform necessary services not required of the contractor. It shall also permit installation of the Mode S sensor and equipment by Government personnel at later sites, at such time when the government may assume this task from the contractor. Therefore, all requirements to prepare the site for installation of the Mode S equipment shall be included. As a minimum, the plan shall contain the following information.

3.15.3.1.1.1 General.- The installation plan shall provide for continuous primary/secondary radar and ATC service with minimal interruption. The contractor shall schedule, coordinate, and staff his efforts for expeditious accomplishment with an absolute minimum of disruption to on-going Government operations and the surrounding neighborhood. Once off-loading of equipment has started, installation work shall proceed on a regularly scheduled basis, without contractor induced lapse, through completion. The plan shall additionally, as a minimum, include a step-by-step procedure for installation of the sensor, including all signal and power interconnections that may be required internal and external to the sensor. All installation hardware required shall be new material both in the sensor and that attached to the radar pedestal and tower. Construction drawings and interface drawings and requirements between the new facility and the existing radar facility shall be provided.

3.15.3.1.1.2 Equipment placement.- A typical floor plan layout for the Mode S sensor operational and maintenance equipment and spares within the building shall be provided. Information on equipment placement limitations, e.g., maximum distances between equipment comprising the system shall be included.

3.15.3.1.1.3 Equipment Description.- A list of the Mode S equipment and tools to be delivered to the site by the contractor shall be provided. This shall include a detailed physical description of the equipment including physical size, weight, clearance factors, cable entry, and exit features. Included also shall be the definition of ventilation and air conditioning requirements, power requirements, equipment circuit breaker panels and requirements, heat load in British Thermal Unit (BTU) per hour, starting surge current data, power factor, conduits, and ducts.

3.15.3.1.1.4 Heating, cooling, and ventilation.- The contractor's proposed installation plan shall include heat, cooling and ventilation calculations for any additional building requirements for Mode S sensor test equipment and maintenance personnel.

3.15.3.1.1.5 Lightning Protection.- The contractor's proposed installation plan shall detail the lightning protection requirements for the Mode S equipment, in compliance with the National Fire Protection Association, Lightning Protection Code, NFPA No. 78 and FAA Order 6950.19. The lightning protection design shall be submitted for Government approval.

3.15.3.1.1.6 Radio frequency interference (RFI) Protection.- The contractor's proposed installation plan shall detail the RFI protection requirements.

3.15.3.1.1.7 Grounding system.- The contractor shall detail the grounding design for the Mode S sensor equipment and provide grounding requirements to the Government in the installation plan. Equipment shall be installed and connected in accordance with the as-built installation drawings (3.15.3.1.2) and with FAA-STD-019 and FAA-STD-020.

3.15.3.1.1.8 Power distribution loading.- The contractor shall provide the power and breaker requirements to the Government in the installation plan.

3.15.3.1.1.9 Cables and connectors.- Definition of cable and connector requirements for the complete installation, including typical cable access points and routing shall be provided.

3.15.3.1.1.10 Space.- Definition of any office equipment and space required by the contractor during the installation, checkout and integration period shall be provided.

3.15.3.1.1.11 Noncontractor services.- Identification of requirements for Government and other contractor's services and test equipment, if any, shall be provided.

3.15.3.1.1.12 Test equipment.- A list of temporary test equipment, if any, which will be supplied by the contractor shall be provided.

3.15.3.1.1.13 Work schedules.- A tabulation of typical or estimated work schedules, requirements and plans shall be provided.

3.15.3.1.1.14 Calibration performance monitor equipment (CPME).- Sensor remote CPME site requirements, including such items as the number of CPME units per site, site location criteria, site equipment, layouts, services required, and antenna tower installation requirements shall be provided for each Mode S installation site, as required in the contract schedule.

3.15.3.1.1.15 Support facilities.- Similar information as described above, where applicable, shall be included in the plan for the PSFs and SSFs to be located at those sites designated in the contract schedule.

3.15.3.1.2 As-Built installation drawings.- Site installation drawings covering all equipment installed and in place for each Mode S sensor shall be provided for each site when contractor installation is required by the contract schedule. The drawings shall include power distribution cabling, signal and control cables, lightning surge protection system, grounding systems, floor plans, and equipment identification as a minimum. The drawings shall be prepared in accordance with FAA-STD-002.

3.15.3.2 Test documentation.- The contractor shall submit on-site test documentation, as required by this specification, to the contracting officer for approval. This documentation shall include test plans, test procedures, and an acceptance data package.

3.15.3.2.1 Test plan.- When required by the contract schedule, the contractor shall submit a single test plan which outlines the complete on-site testing program required to demonstrate compliance of the Mode S equipment with the requirements of this specification. The plan shall provide an overview of all proposed test activities for all equipment and computer programs for the first installation to be performed, as well as each subsequent installation. For each test activity, the plan shall provide specific and detailed test objectives and a thorough discussion of the methods and techniques which are to be used to verify compliance with the requirements herein. The planned start and completion dates, the types and number of units and equipments involved and a listing of all applicable test documentation shall also be provided for each specific test activity. The test plan shall provide for three separate test classifications.

3.15.3.2.1.1 System alignment and checkout.- This section of the plan shall define the sensor and site parameters which must be optimized for the particular site, indicate the necessary system alignments, and define all sensor and site characteristics which must be checked to verify proper installation, in accordance with approved site installation documents and as-built drawings.

3.15.3.2.1.2 On-site acceptance tests.- The plan shall provide for all test activities needed to insure correct functional operation of the sensor both before and after interconnection with the existing sensor and ATC facilities (3.15.10). This shall include test activities to demonstrate proper operation of the Mode S sensor remote monitoring subsystem (RMS) as specified in 3.4.10.6 and 3.5.7 with MPS.

3.15.3.2.1.3 Integration tests.- The plan shall define all test activities needed to insure correct operation of the sensor (3.15.10 and 3.3.2).

3.15.3.2.2 Test procedures.

3.15.3.2.2.1 Equipment and computer test procedures.- The contractor shall prepare comprehensive test procedures which include all details necessary to assure that the test procedures and testing thereto will satisfactorily demonstrate equipment and overall sensor compliance with all functional and performance requirements as specified in this document. Each test of the test procedure shall reference all specific requirements of this document and the appropriate test plan which are to be verified by the test described. The test procedures and data sheets shall comply with the requirements of FAA-STD-016 and FAA-STD-018. Once approved by the Government, these procedures shall be utilized to conduct all testing as required herein.

3.15.3.2.2.2 Integration test procedures.- The contractor shall prepare detailed test procedures which provide assurance that the installed operational equipment is correctly interfaced, as specified in the ICDs, with its associated radar and ATC facilities. The tests shall verify the timing, alignment, and other internal sensor adjustments to adapt the Mode S sensor to the associated equipment. The accuracy of the Mode S sensor data output shall be demonstrated. Once approved by the Government, these procedures shall be used for all integration tests as specified herein. #

3.15.3.2.3 Final test report.- Upon completion of each test defined by the approved test plans and procedures, the test results shall be recorded and submitted to the FAA. The test report shall contain a complete description of the test results. The on-site test report and compliance with all other contract requirements will be used as the basis for acceptance of the on-site installation, testing, and integration at each site. The report, when approved by the Government, shall contain a statement of acceptance of the sensor complex by the Government as meeting the specification requirements and shall provide for the signatures of Government and contractor representatives. The contractor shall certify that each sensor complex submitted for Government acceptance meets all specification and contract requirements. The test report shall contain the data required by the applicable test plan as well as the information specified below.

- a. Site predelivery preparation. The necessary check list to insure that the site predelivery preparation has been accomplished in accordance with the requirements of this specification, and is ready for the installation of the electronic equipment package.
- b. Mechanical and electrical installation. A check list to insure that the installation of the electronic cabinets, cabling (wiring), power wiring, conduit, ductwork, grounding systems, support hardware, etc., have been installed in accordance with specification requirements and

good engineering practices. The acceptance of all electrical and mechanical equipment shall be subject to proper operation in accordance with all requirements of this specification and the approved designs while functioning as a Mode S sensor at each established site.

- c. Test results. Copies of the test data sheets shall be prepared in sufficient detail to accomplish a technical appraisal of the sensor. This shall include a description of the functions tested, the measured performance, and whether the performance meets specified sensor limits. All essential operational parameters, recorded data adjustments data, and meter readings necessary to determine acceptable performance or required for future verification for evaluation and comparison shall be included.

The following information (where applicable) for each parameter and performance datum to be measured and recorded, shall be included:

1. Parameter of performance datum (name, test point, etc.).
2. Measured and specified value.
3. Test equipment used for measurement, calibration date.
4. Equipment control settings.
5. Space for data, photographs.
6. Space for initials of the person making the measurement and an observer.
7. A record of any engineering changes found necessary to correct design deficiencies.
8. Copies of all discrepancies noted during the test along with the dispositions accepted and approved by the Government.
9. A copy of all deviations from the approved test procedures required during the testing, with reason for deviation attached.
10. Copies of all failure reports on components in the equipment under test.
11. An inventory of all installed and spare units as provided in the sensor installation, listed by FAA type number, unit description and unit serial number.

-465-

3.15.4 Sensor installation.

3.15.4.1 Mode S equipment installation.- The contractor shall transport, off-load, set in place and install all equipment. Installation shall be at the locations specified in the contract schedule, and shall include alignment, leveling, attachment of conduit, duct, cable and wires necessary for equipment operation.

3.15.4.2 Power connection.- Government-furnished incoming power will be connected into the Mode S power panel by the Government. All power wiring and materials shall be in accordance with the National Electrical Code, NFPA No. 70.

3.15.4.3 Installation of conduit, ductwork, and wiring.- All wiring, the Mode S sensor conduit and ductwork required to interconnect the electronic equipment (e.g., Mode S sensor and existing ATC sensors, including antenna and APG) shall be provided by the contractor and installed in accordance with the building plans and specifications. This shall include a temporary cutover switch as specified in 3.15.2.1.1, item h. In addition, the contractor shall supply and install all wiring, conduit and ductwork required to interconnect to interfaces with the ATC facilities, radar digitizers, and the Mode S programming and support facilities.

3.15.4.4 Integration.- The contractor shall be responsible for the technical integration of the operational Mode S sensor equipment into the other systems and subsystems specified in 3.5, including the surveillance and communications link connections to the NAS ATC facilities and the communications link connections to the Non-ATC Data Link users. The contractor shall mechanically and electrically connect the Mode S sensor to the colocated radar system and the sensor's surveillance and communications links to the government furnished data transmission equipment (modem, etc) and demonstrate the proper flow of data (e.g., without loss of data and according to the format specified). The interfaces to the systems and subsystems specified in 3.5 shall conform to the appropriate ICD's or other requirements specified herein. When the equipment is to be installed and integrated at the ASR-9 locations specified in the contract schedule, it shall be installed as follows: The Government will provide a building at the specified locations which conforms to the Prefabricated Metal Building Typical Site Construction, drawing number D-6048-1. The location of the ASR-4, -5, and -6 system equipment indicated in drawing D-6048-1 will be utilized by the ASR-9 equipment. The location of the Mode S equipment shall be determined by the contractor, subject to Government approval.

The contractor shall supply all services and materials to verify proper operation of the Mode S sensor and its interfaces. The contractor, with the participation and assistance of the designated FAA representatives, shall align and adjust the Mode S sensor for its optimum performance according to the equipment and operating parameters and requirements of each operational facility. Computer printouts and analysis of the Mode S sensor data will be provided as appropriate by the using ATC facilities. The contractor shall participate in meetings and conferences and provide technical data fully describing the Mode S sensor's performance and design compatibility with the associated equipment as may be directed by the contracting officer. The

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-3

-465a-

contractor shall prepare a Mode S sensor integration procedures manual (3.15.3.2.2.2) which fully describes the adjustments and procedures required for integration of the Mode S sensor into the other systems and subsystems specified in 3.5.

This space intentionally unused

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-3

-465b-

This page intentionally unused

3.15.5 Personnel.- The contractor shall use only experienced, factory trained personnel for installation, integration, testing, and supervision of all field work performed. Subcontractors used by the contractor for rigging, crane service, labor, trash removal, and other miscellaneous work and services shall be the direct responsibility of the contractor and under his direct supervision at all times.

3.15.6 Test equipment and tools.- The requirements of this specification shall apply where practical and necessary for site activities specified herein. The contractor shall provide all cables, cable connectors, terminal boards, adapters, and the like which are required for installation, integration, and site testing of the equipment. Any special purpose test cables, probes, extenders, clamps, or adapters required for routine preventative or corrective maintenance shall be provided. All cables shall be provided to the government with connectors installed, unless proper installation of the cable requires one or both ends to be bare. In such instances, appropriate tools and connector materials shall be provided to each site requiring installation of a connector. Government furnished special test equipment may also be used as mutually agreed to between the contractor and the Government.

3.15.7 Spare parts.- The Government will be responsible for supplying the necessary spare parts for GPE during the installation and checkout phase of the program. The contractor shall maintain a log identifying all parts consumed during the installation, checkout and test phases of the program. The contractor shall supply the necessary spare parts for contractor furnished equipment during the installation, checkout and test phase of the program. Installation spares in the amount of at least ten percent, but not less than three (or equivalent quantity) of each part subject to incorrect installation or damage during installation (such as crimped lugs, ferrules, and heat shrink tubing) shall be provided. If any of the original contractor furnished spare parts are used in the contractor-furnished equipment, the contractor shall replenish those parts so as to provide a complete set of original spares prior to acceptance.

3.15.8 Cleaning.- The contractor shall deliver to the Government a clean installation both inside and out.

3.15.8.1 Interior.- The contractor shall remove all trash and foreign material from the interior of the building and those parts of the facilities housing the SSPs and PSPs. Damage and finish degradation to any building, electronic subsystem interior or exterior surface and other installed equipments resulting from transportation and installation activities shall be repaired or replaced as necessary.

3.15.8.2 Exterior.- All trash, litter, packing damage and excess material shall be removed from the facility area by the contractor. The access road, parking area, facility plot, and building exteriors, etc., shall be left in the same, or better, condition as existed prior to beginning work at the site under this contract.

-467-

3.15.9 Facility commissioning.- The Government will be responsible for all commissioning activities and procedures, including the integration of the Mode S surveillance and communication links into the NAS facilities through the link interfaces specified in 3.5.3.

3.15.10 On-site acceptance test.- The contractor shall perform an on-site acceptance test in accordance with the approved test procedures and the requirements herein. The test program shall consist of at least the following:

- a. Tests that verify the integrity and capability of the Mode S sensor and its supporting equipment to operate correctly using only internal timing and test signals. No alarms or abnormal conditions shall exist that were not present during production tests. No interconnection to the associated radar or data transmission equipment shall be required for this portion of the test. These requirements must be satisfactorily established before proceeding with further tests.
- b. Tests that verify the operational Mode S sensor equipment can operate and process targets from the data provided by the associated radar equipment. The test shall show that the sensor correctly provides and interprets the electrical characteristics of all of the interface signals (3.5.5) which have application at that site. Accurate and alarm-free operation with the associated radar equipment is not required at this time; only a demonstration that live targets and communication data can be processed according to the requirements specified herein. The demonstration may require the verification of some of these requirements by using an off-line data analysis capability.
- c. The contractor shall adapt the Mode S sensor operational equipment to the parameters of the associated radar equipment in accordance with the integration test procedures. During this test, all functions and combinations of functions shall be exercised. As many interfaces and functions shall be active for this test as facility operational requirements will permit. In addition, for the first sensor installation, of each Type, the tests specified in 4.3.3.5 shall be performed suitably adapted for use with live targets of opportunity and test aircraft appropriately instrumented. The description of these tests shall be included in the on-site test plan. For subsequent sensors, a subset of these tests shall be performed as agreed to, and approved by the Government.

Acceptance testing shall not proceed without official Government representation and the contractor shall give advance notice, in accordance with the contract schedule, of intent to start on-site system acceptance testing.

This space intentionally unused.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-3

-467a-

This page intentionally unused

3.16 Configuration and data management.

3.16.1 Configuration management (CM)..- The contractor shall develop and submit to the government, for approval, a Configuration Management Plan (CMP). The CMP shall be prepared in accordance with FAA-STD-021, paragraph 3.2 and FAA-STD-021, Appendix I, paragraph 10.2(c). The CMP shall address the contractors approach to both hardware and software CM. In addition the CMP shall describe the # contractor's data management system: procedure for management, control, and accountability of all data; audit procedures; and subcontractor/vendor control procedures. The CMP shall also describe the methodology and procedures which will be used to manage and control the relationship between a Computer Program # Configuration Item (CPCI) and its using firmware. The contractors CM system shall be capable of identifying which version of a CPCI is to be used to create a specific firmware configuration. This CM system shall provide the necessary levels of control to ensure that the firmware configuration installed in a particular configuration item was created by the correct CPCI version and that the resulting firmware shall perform its intended application. On approval of the CMP by the government, the contractor shall be responsible for implementation of the CMP in accordance with FAA-STD-021.

3.16.1.1 Functional configuration identification (FCI)..- The FCI for the Mode S system is this specification and its associated documentation, and on contract award it is established as the Mode S functional baseline. Subsequent to contract award the FCI shall not be changed without prior Government approval of engineering change requests in accordance with 3.16.2.2.

3.16.1.2 Allocated configuration identification (ACI)..- The ACI for hardware configuration items (CIs) shall be documented by development specifications. A prime item development specification (PIDS) shall be prepared in accordance with 3.13.1.2.1.1, for each CI. A critical item development specification (CIDS) shall be prepared in accordance with 3.13.1.2.1.1, for each critical item within a CI and for each item of deliverable support equipment. Government authentication of the development specifications establishes the Mode S allocated baseline for CIs. The ACI for computer program configuration items (CPCIs) shall be documented by a Functional Requirements Document (FRD) and Software Top Level Design Document (STLDD). A FRD shall be prepared in accordance with 3.13.1.2.5.2. Government authentication of the FRD establishes the Mode S initial allocated baseline for CPCIs. A STLDD shall be prepared in accordance with 3.13.1.2.5.3 for each CPCI. Government authentication of the STLDDs together with the authenticated FRD establishes the Mode S final allocated baseline for CPCIs.

3.16.1.3 Product configuration identification (PCI)..- The PCI shall be documented by product fabrication specifications for each CI. A prime item product fabrication specification (PIPPS) shall be prepared in accordance with 3.13.1.2.1.2, for each CI. A critical item product fabrication specification (CIFFS) shall be prepared in accordance with 3.13.1.2.1.2, for each critical item within a CI and for each item of deliverable support equipment. The PCI for CPCIs shall be documented by software detailed design #

documents (SDDDs). A SDDD shall be prepared in accordance with 3.13.1.2.5.4 for each CPCI.

Government authentication of the PIPFS, CIPFS, SDDDs resulting from successful accomplishment of functional and physical configuration audits (FCAs/PCAs) and a formal qualification review (FQR) establishes the Mode S product baseline for CIs and CPCIs.

3.16.1.4 Configuration item development records (CIDRs).- The contractor shall develop and maintain CIDRs for each CI, CPCI, Critical Item, and Support Equipment Item in accordance with appendix VII of FAA-STD-021. As a minimum the CIDRs shall be reviewed by the government, at Preliminary Design Review (PDR), Critical Design Review (CDR), PCA, FCA and FQR.

3.16.1.5 Interface control.- The contractor shall comply with the requirements of appendix II of FAA-STD-021, with respect to interface control. The contractor shall prepare interface control documents identifying all CI's and CPCI's which have external interface with any and all other equipments/systems, in accordance with FAA-STD-002. All engineering change requests (ECRs) prepared by the contractor affecting CIs or CPCIs, shall identify changes having interface impact upon interface control documents called out in other sections of this specification and shall identify what other equipments and/or systems will be impacted if the change is implemented.

3.16.1.6 Item identification.- The contractor shall comply with the requirements of appendix III of FAA-STD-021, with respect to the identification of engineering, manufacturing and other deliverable products developed/manufactured as a result of this contract.

3.16.2 Configuration control.

3.16.2.1 Specification maintenance.- The contractor, subsequent to government authentication of FCI, ACI or PCI documentation shall comply with the requirements of FAA-STD-005 and FAA-STD-021, appendix VII with respect to the preparation of changes to and maintenance of authenticated FCI, ACI or PCI documentation.

3.16.2.2 Engineering change requests (ECR's).- The contractor shall comply with the requirements of FAA-STD-021, appendix V with respect to changes to the Functional, Allocated, and Product Baselines including all interface control documentation. All Class I ECR's shall be submitted to the government for approval in accordance with the contract. Class II ECR's shall be submitted to the local/resident Government representative for concurrence prior to implementation. Any ECR prepared by the contractor affecting authenticated ACI or PCI documentation shall be reviewed by the contractor for possible impact to the FCI. Any ECR simultaneously affecting more than one baseline shall indicate all changes to all baselines. The contractor shall implement and maintain a single ECR Change Identification Numbering (CIN) System which will contain all ECRs against the FCI and authenticated ACI or PCI documentation.

-467d-

3.16.2.3 Request for deviations or waivers (RFD's/RFW's).- The contractor shall adhere to the requirements of FAA-STD-021, appendix V relative to preparation and submittal of RFD's and RFW's.

3.16.2.4 Engineering release records.- The contractor shall implement and maintain an Engineering Release Record System (ERRS) which is in compliance with the requirements of FAA-STD-021, appendix IV.

3.16.3 Configuration status accounting.- The contractor shall implement and maintain a Configuration Status Accounting System capable of providing Configuration Status Accounting Records (CSAR), reports and data as defined by paragraph 4.9(a) and (b) of FAA-STD-021.

3.16.4 Configuration audits.- The contractor in conjunction with the government shall conduct a Functional Configuration Audit (FCA), Physical Configuration Audit (PCA) and Formal Qualification Review (FQR) in accordance with paragraph 4.8 of FAA-STD-021 and appendices E, F and G of MIL-STD-1521. The PCA for each CPCI shall be conducted prior to initiation of its Formal Qualification Test (FQT) and for each CI prior to its Qualification Tests. The FCA and FQR shall be conducted for each CI/CPCI at the end of the Qualification and Acceptance Test Program and prior to shipment of the CI's and CPCI's to operational sites.

- * 3.17 Life cycle cost.- The contractor shall consider total life cycle cost in evaluating critical design and support options. He shall conduct Mode S total life cycle cost (LCC) analyses in support of the selected design, logistics and maintenance, including those items described below. All LCC documentation shall be provided in accordance with 3.13.5.

3.17.1 Life cycle cost model.- The contractor shall submit a detailed description of his LCC model to the Government for review and approval.

3.17.2 Life cycle cost analysis.- Using the approved LCC model the contractor shall conduct a total life cycle cost analysis to support his design and selected options as decisions are made and as they are modified in each of the following areas:

- (a) Determination of LRU configuration.
- (b) Subsystem and components reliability allocations.
- (c) Critical component selection, including, as a minimum, the receiver/transmitter, computer processor, heating and air conditioning equipment, and other component/module/sub-system, as applicable, that impact life cycle cost of the Mode S.
- (d) Selection of preferred parts list.
- (e) Selection of standard and special support equipment, where a sensor design and acquisition cost exceeds \$10,000 for each specific unit of such equipment for each site.

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-4

-468-

- # 3.17.3 Life cycle cost estimation.- Using the approved LCC model the contractor shall determine the estimated Mode S total life cycle cost for a 20-year life and provide the results of such estimates to the Government. #

This space intentionally unused.

4. QUALITY ASSURANCE PROVISIONS

4.1 General.- The contractor shall establish and maintain a quality control system in accordance with FAA-STD-016 and FAA-STD-018 and the Government approved Quality Control System Plan (3.13.1.12). The Government reserves the right to witness any of the tests used to demonstrate compliance with this specification when such action is deemed necessary by the Government to assure that the equipment and services conform to the prescribed requirements. All of the tests shall be conducted by the contractor in accordance with the test methods in the Government-approved test plan and procedures specified herein. The Government reserves the right to require the contractor to verify requirements, in addition to those contained in the approved test plan, to demonstrate equipment compliance with any paragraph of this specification. The following verifications, as a minimum, shall be conducted on the equipment procured using this specification:

<u>Item</u>	<u>Ref. para.</u>
(a) Quality control inspection	4.3.1 & 4.3.1.1
(b) First article inspection	4.3.1.2
(c) Contractor's preliminary tests	4.3.2
(d) General characteristic tests excluding the Electromagnetic interference test, Item (e)	4.3.3.1
(e) Electromagnetic interference test	4.3.3.1 & 3.3.2.6 of FAA-G-2100
(f) Environmental tests	4.3.3.2
(g) Reliability demonstration test excluding reliability development testing, Item (h)	4.3.3.3
(h) Reliability development testing	4.3.3.3 and 50.3.2.2 of MIL-STD-785
(i) Maintainability test	4.3.3.4
(j) Sensor design qualification test	4.3.3.5 (all subpara. except 4.3.3.5.6)
(k) Type tests	4.3.4 (all subpara.)
(l) Performance type test	4.3.4.1
(m) Production tests	4.3.5
(n) On-Site acceptance test	4.3.7
(o) Integration tests	4.3.8
(p) Sensor/ASR-9 test	4.3.8.1
(q) Sensor/ARTS IIA test	4.3.8.2
(r) Software tests	4.4 (all subpara.)
(s) Sensor hardware/software integration test	4.5

Use of the term "Item" or "items" in section 4 of this specification, refers to the above list of items (a) through (s).

4.1.1 Testing requirements.- The contractor shall furnish all cable, connectors, terminal boards, test cables, test equipment, card extenders, and other similar items as required for the tests and inspections specified herein. Any modifications required to the deliverable equipment to bring it into compliance with this specification as established by these tests shall be incorporated into each equipment by the contractor with no increase in contract price. These modifications and any other performed by the contractor to bring the equipment into conformance with this specification shall be accomplished in accordance with all applicable requirements herein. For example, modifications to intercomponent connections on CCAs using printed wiring shall be accomplished in accordance with FAA-G-2100 as specified in 3.11.2.8.2.2. herein. Equipment changes made during, or at the end of, the testing shall be subject to additional testing to assure compliance with the specification. The necessary retesting shall be determined by the Government. Notice of the contractor's preliminary tests, as well as all other test activities in which the Government retains its right to participate or observe, shall be given as specified in 4.3.1.2 of FAA-G-2100. The system-level testing, except for contractor's preliminary tests, shall not begin until the preliminary equipment instruction books are available.

4.1.1.1. Inspection and testing of sensors

4.1.1.1.1. All sensors.- Except as otherwise required herein, the tests specified in Items (a), (m) and (n) shall be conducted and completed on each sensor procured using this specification.

4.1.1.1.2 Inspection and testing on initial sensors.- In addition to the tests which must be conducted on all sensors, the tests specified in Items (a) through (s) excluding (k), shall be conducted. Not more than the initial (as called for in the contract) Mode S sensors and supporting equipment (3.10.2) presented to the Government may be used for these tests. In order to prevent duplication of effort, only the Performance Type Test, Item (l), portion of the Type Test, Item (k), need be conducted on one of the initial sensors.

All items, except Items (e), (g), (i), (n), (o), (p) and (q), must be conducted and successfully completed prior to delivery of any sensor. Item (p) must be conducted and completed on one of the initial sensors and the results submitted to the Government for approval before acceptance of any sensor. In addition, Items (e), (g), (i), and (o) must be conducted on one of the initial sensors and successfully completed prior to acceptance of the first operational site.

Notwithstanding delivery and/or acceptance of any sensor prior to completion of all the tests required by this section, the contractor shall incorporate into these sensors any modifications required to bring the equipment into compliance with this specification as established by these tests, at no increase in contract price.

Item (c) shall be conducted and successfully completed prior to each of the formal tests and may be witnessed by the Government. Notwithstanding the requirement in 4.3.1 of FAA-G-2100 that Item (c) be conducted "on one production equipment or on one prototype (preproduction model," each Item (c) test shall be conducted on the same sensor on which the formal test will be conducted. The contractor shall perform an Item (c) before Item (m) on one of the terminals and one of the enroute configurations of the sensor.

All items, except Items (a), (b), (d), (h) and (r), shall be conducted on a complete sensor.

Items (e), (f), (j), (o), (p), (q) and (s) must each be separately conducted and successfully completed on one of the initial sensors as a continuous (not cumulative) test on that sensor. Items (e) and (f) shall be conducted using a fully populated sensor.

4.1.1.1.3 Type tests on sensors.- Item (k) tests shall be performed on one production sensor from each type group. Item (k) shall be conducted in accordance with paragraph 4.3.4 of this specification and paragraph 4.3.3. of FAA-G-2100, except that type tests on Group I shall be as set forth in paragraph 4.1.1.1.2.

4.1.1.2 Inspection and testing of other equipment.- Except as otherwise specified for the sensors in paragraph 4.1.1.1, the tests specified in Items (a), (m) and (n) shall be conducted and completed on each other equipment procured using this specification.

In addition, the tests specified in Items (a) through (s), excluding (J) and (k), shall be conducted on the first unit of each equipment procured using this specification. In order to prevent duplication of effort, only the Performance Type Test, Item (l), portion of the Type Test, Item (k) need be conducted on the first unit.

Except as set forth in paragraph 4.1.1.1 above, no equipment shall be released for shipment before the first unit has successfully passed the tests specified in Items (a) through (s).

4.1.2 Recording of test data.- Logs for each of the tests herein shall be prepared by the contractor and submitted as part of the test plan. There shall be two types of logs maintained: an operating log and a maintenance log. Maximum use of cross-referencing between logs shall be made so that both logs contain all incidents and maintenance actions with their appropriate downtime. The logs will be monitored by the Government or its designated representative who will co-sign the logs on a shift basis. The format of the logs shall require Government approval prior to their use.

4.1.3 Test direction.- Factory testing and the on-site tests (3.15) shall be conducted by the contractor. The contractor shall determine when items are ready for test, when corrective action is necessary, and what corrective action is required. After corrective action is completed, the Government will determine if a retest is necessary. Any change to the equipment after it is submitted for test shall require Government approval. If the Government determines that a change is of major significance, the Government may require the test to be repeated.

4.1.4 Failure recording and reporting. - All failures during the test program specified in Items (b) through (s) inclusive shall be recorded and reported in the final test reports (3.13.1.5). Along with a complete summary of the failure as required by 3.9.3.3.9 herein, the following data shall be included:

This space intentionally unused.

- (a) Time of day failure occurred.
- (b) Downtime reported to the nearest minute.
- (c) Time of day when equipment was restored to full service.

For the purpose of these tests, the equipment shall be considered failed if any of the following occurs:

- (a) The Mode S sensor fails to send correct data to any enabled data transmission channel or to the displays or I/O devices used with the performance monitoring and diagnostic functions.
- (b) There are any alarms resulting from a loss of sensor function.
- (c) The Mode S sensor fails to respond within 10 seconds to any legal command as defined in, and entered in accordance with, the procedures in the equipment instruction book.

4.2 Test conditions.- Unless otherwise specified, all test and inspections shall be conducted in a normal human working environment with the equipment subject to ambient air with a temperature of +25° +7°C. The equipment under test shall be supplied with primary power which is within five percent of the design center values of 3.11.1.1. If, during conduct of a test, the approved test plans, procedures, methods, or parameters are found to be inadequately specified, the test shall be held in abeyance until a Government-approved amendment is available. When an approved change is available, the test shall be resumed at the point of interruption, providing that the interruption does not invalidate the test results.

4.3 Tests and inspections.- The contractor shall conduct, analyze, and report the following tests and inspections using the applicable, approved test documentation.

4.3.1 Quality control.- The contractor's quality control program shall be in accordance with FAA-STD-016, FAA-STD-018 and the requirements specified below.

4.3.1.1 Incoming inspection.- The Government may elect to make an incoming inspection of some or all of the parts and materials used in the equipment, to assure compliance with paragraphs 4.5 and related subparagraphs of FAA-G-2100. The successful inspection of the parts and materials shall not constitute final acceptance or approval of their specific applications in the equipment.

4.3.1.2 First article inspection.- The first-built unit, module, and assembly to be provided under the contract shall be given a mechanical and an electrical inspection. The mechanical inspection shall include a visual examination to determine compliance with the applicable specification requirements covering strength and rigidity, accessibility, types of components and materials, choice of insulation, layout of chassis, panels and wiring, finishes, workmanship, and similar attributes. The electrical inspection (or bench test) shall include tests which determine the compliance of the equipment with all application specifications, including those of the contractor, which cover electrical requirements and performance. Electrical continuity, leakage resistance, power supply voltages and regulation, battery backup, display operation, clock accuracy and stability, and similar

characteristics shall be included. In the event that the contractor determines that certain specification requirements do not have to be so inspected for quality control, it may request waivers for those items from the Government in writing. Units built and successfully inspected may be retained temporarily by the contractor as the contractor's property in order to enable testing and integration with associated units. However, all such units shall be mechanically and electrically reinspected prior to delivery to the Government as part of the complete, deliverable system.

4.3.2 Contractor's preliminary tests.- The contractor shall perform preliminary tests in accordance with 4.3.1 of FAA-G-2100.

4.3.3 Design qualification tests.- The contractor shall perform the following design qualification tests as a minimum:

4.3.3.1 General characteristics tests.- The general characteristics tests shall be conducted in accordance with paragraphs 4.3.2.1 and 4.3.2.2 of FAA-G-2100 except that the noise level test of Table V is required on each complete, deliverable equipment type. The tests shall also verify compliance with the general design requirements of 3.11 and related subparagraphs herein.

4.3.3.2 Environmental tests.- The environmental tests shall demonstrate that the equipment functions correctly under the aircraft, radar, and service condition requirements specified in paragraph 3.3.2 and 3.11.1 and their related subparagraphs herein. This includes the capacity and response time requirements of 3.3.2.5. In addition, the requirements of 3.7.2.3.1 shall also be tested. If procured, the input simulator (Appendix IX) shall be used as the source of the input signals required for these tests, unless a specific exemption is granted by the Government. In addition, when using the input simulator, the contractor shall use instrumentation recordings of aircraft data as the source of the simulated input signals. The specific tapes to be used shall be approved by the Government before testing begins. Government assistance in the preparation of the tapes may be provided if requested by the contractor.

The barometric service condition test shall be in accordance with the requirements of paragraph 4.9 of FAA-G-2100. The option chosen by the contractor shall verify the capability of the sensor to perform correctly over the specified range of altitudes. If the contractor selects the maximum simulated altitude test option, then the actual test of the equipment's performance after at least five hours at each pressure extreme shall be performed. Normal temperature and humidity conditions are acceptable during the pressure test.

If the contractor elects to run the altitude test (4.9 of FAA-G-2100) at the test site, he shall select the first sensor to be installed over 10,000 feet as his first test site (Cedar City, Utah). The successful completion at that site of the on-site acceptance test (3.15.10), shall constitute acceptance of the altitude test. Any equipment changes required to effect passage of this altitude test shall be incorporated in all sensors.

-473-

The temperature and humidity service condition test shall be conducted in accordance with paragraph 4.11 of FAA-G-2100.

The electrical service condition test shall be conducted in accordance with paragraph 4.8 of FAA-G-2100 and the requirements herein. A test at each extreme of line frequency shall be performed. With the line frequency at the normal test value, tests shall be performed over the line voltage service condition range. The equipment's performance in the presence of electrical transients shall be demonstrated by testing unless specific exemption is granted by the Government. Such exemptions will only be issued in response to a request from, and with satisfactory technical analysis and justification by, the contractor. The start-up surge and power consumption tests shall be accomplished under normal test conditions.

The equipment shall be exposed to the non-operating temperature, humidity, and altitude extremes, in any combination (at the contractor's option), for at least two hours before being returned to values within the operating conditions.

The contractor shall supply cabling of the appropriate, type and the maximum length required for all interface signals (3.5) from the operational Mode S sensor. The output signals shall be tested to verify that they meet the applicable requirements at the end of this cabling.

4.3.3.3 Reliability test and demonstration.- The reliability test and demonstration shall be conducted in accordance with the reliability test plan (3.13.1.3.1) and the requirements herein. Reliability development testing shall be performed in accordance with 50.3.2.2 of MIL-STD-785. The development tests shall be designed to identify problem areas, detect latent defects, and underscore deficiencies such that the corrective actions required to cause incremental reliability growth can be implemented as the equipment development proceeds. Development test results and data shall be included in the reliability status reports (3.13.2.1.2). A reliability demonstration test shall be conducted on the sensors specified herein; the intent of this test is to establish equipment specification compliance (3.9.2) to the degree possible under a time-limited test. The test shall be conducted under the combined environmental test conditions for Category I of equipment in accordance with MIL-STD-781 to produce a discrimination ratio of 2, 20 percent risk, and realistic environmental conditions. The contractor shall analyze and evaluate the test data as stated in the test plans.

Using MIL-STD-781, Test Plan XIVc, a fixed time test of channel MTBF (MTBCF) shall be performed, with an upper test MTBCF (θ_0) requirement of 1100 hours and a lower test MTBCF (θ_1) requirement of 550 hours such that 4,300 channel hours are accrued (2,150 sensor hours with both channels operating). The channel MTBCF test shall be conducted without repair of any operational, standby, or redundant elements, within either channel under test, until a channel failure is recorded. Upon a channel failure, repair shall be allowed only in the failed channel.

As an alternative to the test specified above, the contractor may conduct an alternative reliability demonstration test of the MTBCF, which shall insure that no more than 16 visits per year are made to the sensor site for #

* corrective and preventive maintenance tasks. During the alternative test, the site visits shall include provisions for conducting all of the necessary preventive and corrective maintenance tasks on both channels of the sensor. Any channel failure shall require a site visit for corrective maintenance. The corrective maintenance tasks shall include repair or replacement of all failed elements of both channels at the sensor site including operational, standby, or redundant elements. Based on MTL-STD-781, Test Plan XIVc, the alternative test shall be run for 4,300 channel operating hours (2,150 sensor hours with both channels operating). The test will be successful if 5 or less site visits for maintenance are recorded during the test. †

If the test is failed per Test Plan XIVc, the contractor shall correct the problem(s) and the Government reserves the right to have the contractor restart the reliability demonstration test. The parameters necessary to adequately establish proper information shall be measured and recorded at least once every 12 hours.

-473b-

FAA-E-2716 & AMEND.-2
SPECIFICATION CHANGE-5

#

This page intentionally unused.

#

The demonstration test shall be conducted in accordance with 5.4 through 5.12 of MIL-STD-781 except where otherwise required herein. The tests shall continue 24 hours per day, seven days a week until an accept-reject decision can be made. During the test, all preventive maintenance prescribed for normal operational deployment of the equipment shall be performed by the contractor. Data on all failures and corrective and preventive maintenance times shall be recorded during the test, even if the failures or maintenance tasks involved no loss of data and, thus are not counted as "failures" in the reliability test. This maintainability data is in addition to that required elsewhere herein.

4.3.3.4 Maintainability test.- The maintainability demonstration test shall be conducted in accordance with test plan (3.13.1.3.2) and the requirements herein. The test shall be conducted under simulated operational conditions and shall establish whether or not the Mode S sensor and its supporting equipment meet the maintainability requirements of 3.9.2.2 herein. The downtime shall begin with the loss or degradation of a capability to a user and shall stop with the restoration of the full capability to that user. Test Method 1, Test Plan B of MIL-STD-47, Appendix B, shall be used with a consumer's risk value of 0.10. Appropriate corrective maintenance tasks for each equipment shall be generated by fault simulation in accordance with paragraph 4.3.1.2 and Appendix A of MIL-STD-471. The number of tasks shall be as specified by paragraph B.10.3 of MIL-STD-471 or 50, whichever is greater. The specific corrective maintenance tasks shall be proposed to, and approved by, the Government as part of the test procedures (3.13.1.3.1). The preventive maintenance tasks tested shall consist of all those tasks prescribed for normal operational deployment of the equipment.

The tests shall be administered in accordance with the requirements of paragraph 4.4 of MIL-STD-471. The appropriate maintenance procedures described in the equipment instruction book (3.13.2.2) shall be followed during the performance of this test. Whenever possible, the maintenance activities shall be performed on the off-line channel or supporting equipment.

4.3.3.5 Sensor design qualification test.- The following tests, as a minimum, shall be performed on one of the initial Mode S sensors and its supporting equipment. Each test shall be performed on this system as installed on-site, or at the factory (except 4.3.3.5.4), according to the Government-approved test plan; the contractor shall state in his proposed test plan the rationale for performing a test at the factory or on-site.

4.3.3.5.1 Receiver testing requirements

4.3.3.5.1.1 Overall receiver requirements assurance.- The requirements stated in 3.4.3.2 shall be verified by direct measurement. Measurements over the full frequency range shall be taken at frequencies 0.5 MHz apart. Measurements specified over the dynamic range shall be taken every 10 dB within the specified dynamic range.

4.3.3.5.1.2 Monopulse channel.- Photographs of the input to the monopulse A/D shall be taken for standard RF pulse inputs (3.4.3.2.1) ranging over the full frequency and dynamic range of the inputs. This set of photographs shall be retaken for short trapezoidal pulses (350 ns wide at 50 per cent amplitude level) ranging over the full frequency and dynamic range of the inputs.

4.3.3.5.1.3 Video pulse quantizer.- Photographs showing both log $|I|$ waveforms and VPQ output waveforms (SQED and ELE) shall be provided for the following RF pulse inputs to the I channel ranging over the full dynamic and frequency range (using standard test pulses as described in 3.4.3.2.1):

- (a) Single standard trapezoidal pulse.
- (b) Two standard trapezoidal pulses overlapping with leading edges separated by 200 ns, equal amplitudes.
- (c) Same as (b) except later pulse \pm 9 dB relative to earlier one.
- (d) Same as (b) except later pulse \pm 18 dB relative to earlier one.
- (e) Same as (b) except for 300 ns leading edge spacing and equal amplitudes.
- (f) Same as (e) except later pulse \pm 9 dB relative to earlier one.
- (g) Same as (e) except later pulse \pm 18 dB relative to earlier one.
- (h) Same as (b) except for 500 ns leading edge spacing and equal amplitudes.
- (i) Same as (h) except later pulse \pm 9 dB relative to earlier one.
- (j) Same as (h) except later pulse \pm 18 dB relative to earlier one.

4.3.3.5.2 Positional accuracy tests at various power levels and frequencies.- In addition to satisfying the stated component requirements that pertain to range and azimuth measurements, an overall system positional accuracy shall be demonstrated based upon the following tests. In these tests provision shall be made to record the range and azimuth estimate for each reply while varying the CPME test set over the parameters specified below for transmitted power, frequency, and the antenna azimuthal beam position. When these parameters are varied as specified, the range and azimuth bias and jitter values, as indicated in 4.3.3.5.2.4, shall not exceed the values specified in the accuracy requirements (3.3.2.7 and 3.3.2.8). Separate measurements shall be made with the CPME responding in Mode S and in the ATCRBS mode.

In addition, accuracy tests shall be conducted in the presence of synthetically generated ATCRBS fruit (4.3.3.5.2.5). With the fruit levels specified, the errors shall not exceed the specified values.

Use of special (non-operational) test software will be permitted for the conduct of these tests.

4.3.3.5.2.1 Test set transmitted power.- The transmitted power of the test set shall be adjusted such that the power received at the sensor RF port, with the test set on boresite, is as follows: nine level settings in increments of 5 dB each, starting from -64 dBm, \pm 3 dB.

4.3.3.5.2.2 Test set frequency.- The transmitted frequency of the test set shall be adjusted to the following nominal frequencies: 1087, 1088, 1089, 1089.5, 1090, 1090.5, 1091, 1092, 1093 MHz.

4.3.3.5.2.3 Antenna beam locations.- The sensor shall interrogate the CPME at a high enough rate and over a sufficient number of scans to accumulate at least 500 replies spaced across the following Mode S and ATCRBS beamwidths for each of the above 81 power and frequency combinations. Two Mode S beamwidths are specified for these tests. One is defined as the azimuth region corresponding to $+1.5 > \Delta/I > +0.5$. The other is defined as the azimuth region corresponding to $+0.5 > \Delta/I > -0.5$. The ATCRBS beamwidth is defined as the azimuth region corresponding to $+1 > \Delta/I > -1$.

4.3.3.5.2.4 Data Presentation.- An azimuth and range estimate of the CPME position shall be derived and recorded for each CPME reply received within the above defined beamwidth. The first 500 position estimates within the beam for each power/frequency combination shall be used to compute a mean error (bias), a standard deviation (jitter) error, and an RMS error. These values shall be recorded in the test report. The bias and jitter values, derived from separate Mode S and ATCRBS measurements for each of the defined beamwidths, and for each power and frequency combination, shall be as follows:

	Mode S		ATCRBS
	Frequency Range		Frequency Range
	1089 to 1091 MHz	1087 to 1093 MHz	1087 to 1093 MHz
Azimuth bias error	$< \pm 0.033^\circ$	$< \pm 0.066^\circ$	$< \pm 0.066^\circ$
Azimuth jitter error	$< 0.060^\circ, 1\sigma$		
Total azimuth RMS error (alternative)	$< 0.068^\circ$		
Range bias error	$< \pm 30$ feet		
Range jitter error	< 25 feet, 1σ		

4.3.3.5.2.5 Testing in a fruit environment.- A subset of the above tests shall be run in the presence of synthetically generated fruit. The subset is defined as follows:

Test set transmitted power: -64 ± 3 dBm at the sensor RF port

Test set frequency: 1090 MHz

Antenna beam location: Same procedure as in 4.3.3.5.2.3, except that at least 1000 replies shall be accumulated for the one power x frequency combination.

Data presentation: Same procedure as in 4.3.3.5.2.4, except that 1000 measurements shall be used to compute the rms error.

While collecting the above 1000 measurements, synthetic fruit shall be entered into the sensor sum, difference, and omni RF channels using the Aircraft Reply and Interference Environment Simulator (ARIES). This simulator will generate ATCRBS fruit randomized in range, azimuth, and signal strength.

All fruit will be generated statistically independent of other fruit, and mainlobe fruit shall be uniformly distributed over the full unambiguous monopulse beamwidth (B_m) of the monopulse processor.

The mainlobe fruit will have a power level referred to the sensor RF port determined as follows:

$$P_{m1} = (-20 - 20 \log r_{m1}) \text{ dBm},$$

where r_{m1} is random and uniformly distributed between 1 and 100.

The omni signal level associated with each mainlobe fruit will be adjustable between 10 and 25 dB below the mainlobe sum channel signal level. The test value shall be selected to match the average omni value gain of the Mode S sensor antenna being used.

The sidelobe fruit will have a power level referred to the sensor RF port determined as follows:

$$P_{s1} = (-55 - 20 \log r_{s1}) \text{ dBm},$$

where r_{s1} is random and uniformly distributed between 1 and 32. Sidelobe fruit is not generated at power levels below -85 dBm.

The timing of fruit arrivals will be distributed according to a Poisson process. It will be set at an average rate of 24,000 mainlobe plus sidelobe fruit per second exceeding the sensor MUSL (-79 dBm referred to the sum channel RF port). This rate of arrival fruit above MUSL is obtained by generating approximately 46,000 fruit per second exceeding a level of -85 dBm.

Mainlobe and sidelobe fruit will be randomly interspersed. The ratio of average sidelobe to mainlobe fruit generation rates shall be

$$\frac{N_{s1}}{N_{m1}} = \frac{32(360 - B_m)}{100B_m}$$

With an average fruit rate above MUSL of 24,000 per second, the rms error of azimuth measurements shall not exceed 0.06 degree, rms.

4.3.3.5.3 Positional accuracy tests using functional software.- The range and angle accuracy values specified in 3.3.2.8 shall be demonstrated via the CPME using functional sensor software and the following values: a) ATCRBS PRF = nominal specified, and b) scheduled Mode S sensor interrogation off-boresight angle (THETAHALF) = 45 Au (1°). Separate measurements shall be made with the CPME test set responding in Mode S and in the ATCRBS mode. Mode S measurements shall be made when the sensor is in the roll-call mode. These tests shall be conducted after the sensor has been calibrated according to the operationally compatible test procedures specified in 3.3.2.7.

The test set power shall be set to a power level to produce the greater of either the received power level specified in 3.3.2.8 or -64 dBm. The test set frequency shall be set to 1090 MHz. Each measurement will include at least 500 replies.

4.3.3.5.4 Accuracy tests with airborne transponder.- Range and azimuth jitter shall be measured using the operational sensor software and parameters described in 4.3.3.5.3 and a government furnished aircraft equipped with a Mode S and/or an ATCRBS transponder. The flight trajectory shall be such that a direct outbound radial flight path from the sensor will be described. The chosen flight path shall avoid sources of diffraction or multipath effects. Several repetitions may be made at various values of aircraft altitude. For each repetition, the aircraft will, to the extent possible, maintain a constant speed, heading, and altitude. The sensor-to-aircraft elevation angle and range (i.e., received power level) will be restricted to the envelope specified in 3.3.2.8. The live flight tests may be conducted at the contractor's facility and/or at the completion of the site installation. The locale and number of such tests will be explicitly stated in the contract schedule.

Range and azimuth jitter measurements shall be made using a 9-point sliding window, second order, least-squares curve-fit technique described in FAA-RD-76-219, Appendix B. The bad point rejection test described therein shall be used to reject a data point for the fitting of the polynomial, but not to exclude the data point from the jitter calculations. The jitter is defined to be the standard deviation of the array of measured values given by the difference between the reported value (range or azimuth) and the corresponding curve value. Intervals with 2 or more missing reports will be excluded from the calculation.

The measured jitter for any of the runs shall be less than specified in 3.3.2.8.

4.3.3.5.5 Sensor performance with simulated scenarios.- The Mode S sensor shall perform surveillance and communications processing to provide the following minimum performance using the ARIES, a communications input driver and GFE aircraft scenarios. These minimum performance measures pertain only to the simulated scenarios specified below and shall not relieve the contractor from fulfilling the rest of the requirements specified in this specification.

Two GFE aircraft scenarios will be extracted from the Los Angeles traffic model described in FAA-RD-81-39. These aircraft scenarios and the communications driver will provide a sensor surveillance and communications loading that does not exceed the capacity requirements of 3.3.2.5.

Input parameters used to generate the ARIES traffic model type will be as follows:

Beacon reply probability	= 0.93
Radar blip scan ratio	= 0.8
ARIES effective beamwidth	= 3.5°

ARIES fruit input:

ATCRBS

Rate	= 4000/second
Fraction main beam	= 0.30

Mode S

Rate	= 50/second
Fraction main beam	= 0.30
Fraction long replies	= 0.25

Minimum sensor performance shall be as follows:

	<u>ATCRBS</u>	<u>Mode S</u>
Beacon blip/scan ratio	> 0.97	> 0.98
Effective blip/scan ratio (includes radar substitution)	> 0.99	> 0.99
Report Code validity	> 0.97	> 0.999
Report Altitude validity	> 0.95	> 0.999

	<u>ATCRBS</u>	<u>Mode S</u>
False reports due to splits and fruit	< 0.3%	< 0.1%*
Track swaps	< 1%	N/A
Time in storage (correlating user)	< 3/32 scan	< 3/32 scan
Average reinterrogation rate	N/A	< 0.10
Communications messages		
% delivered	N/A	> 99%
Maximum delivery time	N/A	< 2 scans

The following definitions apply to the system performance specified above:

Blip/scan ratio - The number of antenna scans in which a target report, for any given aircraft, is generated by the Mode S sensor divided by the total number of elapsed scans over which the blip/scan ratio is being measured.

Code Validity - The number of beacon reports with correct identity code generated by the Mode S sensor divided by the total number of beacon reports generated during the measurement period.

Altitude Validity - The number of beacon reports with correct altitude code generated by the Mode S sensor divided by the total number of beacon reports generated during the measurement period.

False Reports - Any target report not associated with an ARIES aircraft or a multiple report for any ARIES aircraft.

Track Swap - An interchange of surveillance file numbers between adjacent aircraft.

4.3.3.5.6 Sensor radar tracking performance with simulated scenario. - The Mode S sensor shall demonstrate radar report tracking performance using ARIES with a government-furnished aircraft scenario. The aircraft scenario will generate a maximum of 54 radar reports per scan. These reports are distributed over 360 degrees within 60 nmi of the sensor. Each radar report will have the following parameters:

Doppler 1 = 3
Doppler 2 = 3
Interpolated Doppler 1 = 7
Interpolated Doppler 2 = 7
Quality = 3
Confidence = 1

*All-Call reports.

Radar track blip-scan ratio shall be 99 percent, minimum, excluding coasts due to missing reports per the input scenario.

4.3.4 Type tests.- The Government shall designate one production system for type testing from each type group. Systems manufactured prior to selection of the type test system, and those systems manufactured during type testing shall undergo production testing, and shall be shipped with Government acceptance conditional upon successful completion of that group's type tests. Changes required as result of type testing shall be incorporated into systems in production and by retrofit into all previously shipped systems of that type at the contractor's expense. The contractor shall perform the following type tests as a minimum.

4.3.4.1 Performance type test.- This test shall establish that each deliverable equipment, including its subsystems, units, modules, etc., fully satisfies the requirements of 3.11, and where applicable, the requirements of 3.4, 3.5, 3.6, and 3.7, and 3.8 and all related subparagraphs. The test shall be conducted in accordance with approved test plans and procedures and shall verify at least the following functions, as applicable to the equipment under test:

<u>Function</u>	<u>Reference Paragraph</u>
(a) Overall performance	3.3.2
(b) Transmitter/modulation control	3.4.2
(c) Multichannel receiver	3.4.3
(d) Channel management	3.4.1
(e) Mode S reply processing	3.4.4
(f) ATCRBS reply processing	3.4.5
(g) Surveillance processing	3.4.6
(h) Data link processing	3.4.7
(i) Network management (as applicable)	3.4.8
(j) (Not used)	
(k) Performance monitoring	3.4.10
(l) Sensor calibration	3.4.11
(m) Sensor start-up	3.4.12
(n) System timing	3.4.13
(o) Test target generator	3.4.14
(p) External interface requirements	3.5 and Applicable Appendices

4.3.4.2 Production reliability verification type test.- The production reliability verification type test shall be conducted in accordance with the reliability test plan and the requirements herein. The tests shall be similar to the reliability demonstration test (4.3.3.3), based on channel MTBF, except that test plan IV-C of MIL-STD-781 shall be used in lieu of test plan XIV-C, and the test shall not be time-limited.

4.3.4.3 Temperature and humidity type tests.- These type tests shall be identical to the same tests performed as a part of the environmental design qualification tests (4.3.3.2).

4.3.5 Production tests.- System production tests shall be performed on all subsystems and all ancillary units of each complete Mode S sensor and its supporting equipment procured under this specification. Tests shall be conducted using simulated inputs and suitable instrumentation to verify that the equipment complies with the major requirements of this specification. The spare CCAs and other assemblies supplied as spares with the system shall be substituted for like items during system tests. Certain tests which may be impractical to perform with the equipment operating as a complete system, may be performed on a bench test or group test basis only when specifically approved by the Government. System production tests shall be as specified in the test plan and procedures and shall include, as minimum, the tests of paras. 4.3.4.1(a), (b), (c), (e), (f), and (g) herein. The type tests shall be reduced in scope to serve as production tests as authorized in the approved test plan. The production test shall include a complete (to the greatest extent possible, considering the lack of actual radar inputs) calibration and alignment of the equipment in accordance with the instruction book procedures. Following the production performance test, the equipment shall be operated continuously for at least 70 hours to demonstrate satisfactory performance in accordance with this specification. This test is a burn-in period designed to demonstrate continuous equipment performance for a several-day period without a relevant failure (3.9.1). An accurate log of any failures and subsequent corrective action taken shall be kept for each deliverable item to determine whether failures are repetitive and whether design changes are warranted. A copy of the equipment failure log shall be shipped with the equipment to the site. The following procedure shall be followed during the burn-in test:

- (a) After a warmup period of approximately 20 minutes, the equipment shall be aligned for optimum performance in accordance with the instruction book procedures. No further adjustments will be allowed for the duration of the test.
- (b) Test measurements shall be taken at least every 12 hours during the test.
- (c) The equipment shall be operated continuously, with a simulated target load of at least 200 targets per scan. The Mode S test target generator may be the source for these test signals.
- (d) A more comprehensive test, to include the use of data entry devices and other normal operating controls shall be performed at least every 12 hours.
- (e) During the last 12 hours of the test, each front end of the sensor shall be alternately de-energized for at least 0.5 hour and energized for

at least one hour. This shall be repeated at least two times during the 12-hour period. Minimum acceptable performance during this period is continuous simplex operation.

(f) During the last half hour of the test, a simulated power failure test shall be made. All power to the equipment shall be interrupted for at least 30 seconds and then reapplied. When power is restored, the operational Mode S equipment shall resume normal operation without requiring any equipment adjustments or manual intervention. The supporting equipment (3.10) shall come up in an idle state with no damage, errors or faults other than those which are corrective by reinitialization of the activity in progress at the moment of power loss.

(g) All observations of malfunctioning or instability in the system shall be recorded on test data sheets (3.13.1.4) which shall serve as a log or history of the test. Entries into the log may be made by the Government representatives without concurrence of the contractor's representatives and vice versa. The contractor shall include proposed pass-fail criteria in the test plan which are consistent with the reliability requirements.

(h) All specification requirements shall be met during the test period without readjustment of controls, other than normal operational controls.

The production test shall also include an inspection of preservation, packaging, packing, and marking of material for shipment and storage to assure conformance with the requirements of 3.0 herein.

4.3.6 Availability calculation.- The availability of the operational Mode S sensor shall be established using data from the reliability test and demonstration (4.3.3.3), the maintainability test (4.3.3.4) and, if necessary, the production reliability verification test (4.3.4.2) and the burn-in portion of the production tests (4.3.5). Only data taken during the time when the sensor is operating with the redundant front ends specified in 3.7.2 shall be used for this calculation. System downtime as the result of preventive maintenance shall not be counted, provided that the recovery requirements of 3.9.1 are met. The recovery shall be successfully demonstrated at least twice for each such preventive maintenance routine before its downtime is deducted from the total downtime.

4.3.7 On-site acceptance test.- Upon completion of the contractor's installation of equipment at an operational or a non-operational facility, the contractor shall perform an on-site acceptance test in accordance with the approved test plan and the requirements herein. The test shall consist of at least the following:

(a) The test shall verify that the installation has been correctly completed in accordance with the approved site installation documents and as-built drawings.

- (b) The test shall verify the integrity and capability of the Mode S sensor and its supporting equipment to operate correctly using only internal timing and test signals. No alarms or abnormal conditions shall exist that were not present during production tests. No interconnection to the associated radar or data transmission equipment shall be required for this portion of the test. These requirements must be satisfactorily established before proceeding with further tests.
- (c) The test shall verify that the operational Mode S sensor equipment can operate and process targets from the triggers, videos, and azimuth data provided by the associated radar equipment. The test shall show that the Mode S sensor correctly provides and interprets the electrical characteristics of all of the interface signals (3.5) which have application at that site. Accurate and alarm-free operation with the associated radar equipment is not required at this time; only a demonstration that live targets and communication data can be processed according to the requirements specified herein. The demonstration may require the verification of some of these requirements by using an off-line data analysis capability. If off-line data analysis is used to verify any of these requirements, the data shall be presented to the Government's on-site representative within 24 hours after completion of the test.

4.3.8 Integration tests.- The contractor shall adapt the Mode S sensor operational equipment to the parameters of the associated radar equipment in accordance with the integration test procedures (3.13.1.10). During this test, all functions and combinations of functions shall be exercised. As many interfaces and functions shall be active for this test as facility operational requirements will permit.

4.4 Software test requirements

4.4.1 Informal software testing.- The contractor shall conduct informal software testing in accordance with the requirements of 4.4.1.1 and 4.4.1.2 for all MODE S system software developed. Formal testing shall be conducted in accordance with 4.4.2. The Government shall have access to all informal test information and results.

4.4.1.1 Module (unit) tests.- Prior to start of preliminary qualification tests (PQTs) the contractor shall conduct (informal) module level tests. For each module, the contractor shall maintain a unit test folder which shall contain, as a minimum, a description of each specific MODE S program functional/performance requirement designed into the module, the objective of each test conducted, the test steps invoked, the test result(s) and the date each test was conducted. The tests shall be witnessed by software quality assurance (SQA) personnel and on conclusion of each test the SQA representative shall affix a SQA identification stamp and date on each test data sheet indicating that satisfactory/successful test results were achieved for each program functional/performance requirement identified.

at least one hour. This shall be repeated at least two times during the 12-hour period. Minimum acceptable performance during this period is continuous simplex operation.

(f) During the last half hour of the test, a simulated power failure test shall be made. All power to the equipment shall be interrupted for at least 30 seconds and then reapplied. When power is restored, the operational Mode S equipment shall resume normal operation without requiring any equipment adjustments or manual intervention. The supporting equipment (3.10) shall come up in an idle state with no damage, errors or faults other than those which are corrective by reinitialization of the activity in progress at the moment of power loss.

(g) All observations of malfunctioning or instability in the system shall be recorded on the test data sheets (3.13.1.4) which shall serve as a log or history of the test. Entries into the log may be made by the Government representatives without concurrence of the contractor's representatives and vice versa. The contractor shall include proposed pass-fail criteria in the test plan which are consistent with the reliability requirements.

(h) All specification requirements shall be met during the test period without readjustment of controls, other than normal operational controls.

The production test shall also include an inspection of preservation, packaging, packing, and marking of material for shipment and storage to assure conformance with the requirements of 5.0 herein.

4.3.6 Availability calculation.- The availability of the operational Mode S sensor shall be established using data from the reliability test and demonstration (4.3.3.3), the maintainability test (4.3.3.4) and, if necessary, the production reliability verification test (4.3.4.2) and the burn-in portion of the production tests (4.3.5). Only data taken during the time when the sensor is operating with the redundant front ends specified in 3.7.2 shall be used for this calculation. System downtime as the result of preventive maintenance shall not be counted, provided that the recovery requirements of 3.9.1 are met. The recovery shall be successfully demonstrated at least twice for each such preventive maintenance routine before its downtime is deducted from the total downtime.

4.3.7 On-site acceptance test.- Upon completion of the contractor's installation of equipment at an operational or a non-operational facility, the contractor shall perform an on-site acceptance test in accordance with the approved test plan and the requirements herein. The test shall consist of at least the following:

(a) The test shall verify that the installation has been correctly completed in accordance with the approved site installation documents and as-built drawings.

(b) The test shall verify the integrity and capability of the Mode S sensor and its supporting equipment to operate correctly using only internal timing and test signals. No alarms or abnormal conditions shall exist that were not present during production tests. No interconnection to the associated radar or data transmission equipment shall be required for this portion of the test. These requirements must be satisfactorily established before proceeding with further tests.

(c) The test shall verify that the operational Mode S sensor equipment can operate and process targets from the triggers, videos and azimuth data provided by the associated radar equipment. The test shall show that the Mode S sensor correctly provides and interprets the electrical characteristics of all of the interface signals (3.5) which have application at that site. Accurate and alarm-free operation with the associated radar equipment is not required at this time; only a demonstration that live targets and communication data can be processed according to the requirements specified herein. The demonstration may require the verification of some of these requirements by using an off-line data analysis capability. If off-line data analysis is used to verify any of these requirements, the data shall be presented to the Government's on-site representative within 24 hours after completion of the test.

4.3.8 Integration tests.- The contractor shall adapt the Mode S sensor operational equipment to the parameters of the associated radar equipment in accordance with the integration test procedures (3.13.1.10). During this test, all functions and combinations of functions shall be exercised. As many interfaces and functions shall be active for this test as facility operational requirements will permit.

4.3.8.1 ASR-9 interface tests.- The contractor shall conduct formal tests to verify the operation of the Mode S sensor with the ASR-9 system. These tests shall be conducted using a complete Mode S sensor including CPME, Surveillance Data Selector (SDS), a complete ASR-9 radar site system, radar/beacon antenna systems identical to that to be used at FAA field sites, local control terminal and targets of opportunity or flight test aircraft. The tests shall verify the physical, electrical and protocol compatibility of the Mode S sensor with the ASR-9. Included in these tests shall be:

(a) The verification of the two way transfer of data and control between the Mode S and the ASR-9 as defined in 3.5.2.4, 3.5.2.4.1 and the ICD's for the Mode S/ASR-9 interface and the Sensor/Local control terminal interface.

(b) The measurement and calculation of the following Mode S/ASR-9 (search radar) system performance parameters using a combination of scheduled flights and targets of opportunity.

Search and Beacon Blip/Scan ratios

RMS Range and Accuracy Errors for the search data as compared to the beacon data

Beacon Code Validation

Percent false beacon reports

Number of RADAR only reports (no beacon correlation)

Percent of beacon target reports which are RADAR reinforced

Percent of beacon tracks for which RADAR substitution occurs

Performance of the above parameters shall be measured for both ATRBS and Mode S modes while working with the ASR-9 and shall comply where applicable with the requirements of Sections 3.3, 3.4, and 3.5 of FAA-E-2716. Retesting of requirements in 3.4 and 3.5 previously verified and unrelated to either search radar processing or search/beacon reinforcement or substitution is not required.

(c) The verification of all Mode S/ASR-9 modes (as listed below) and the generation of correct SDS output messages for various subsystem unavailabilities. The various modes (as listed below) result from equipment failure in either the Modes S or the ASR-9 system. Each mode shall be tested to verify the correct routing of data, and to measure the equipment functional performance and information provided to ATC. As a minimum, the following modes shall be tested.

1) Normal System Mode - Outputs from the SDS are Radar/Beacon Reinforced messages with the Beacon data originating in the Mode S sensor. The outputs shall meet the requirements items of (a), (c), (e), (f) and (h) of section 3.9.2.1 when redundant channels of either the ASR-9 and/or the Mode S are subjected to either a manual or an automatic channel switch. Retesting of requirements in section 3.9.2.1 previously verified and unrelated to the Mode S / ASR-9 interface is not required.

2) Back-Up Mode - Outputs from the SDS are Radar/Beacon reinforced messages with the Beacon data provided by the Mode S Beacon video and ASR-9 Beacon Target Detector (BTD) combination.

3) Mode S only Mode - The Mode S is operational and the ASR-9 is disabled. Outputs from the SDS shall be Beacon only messages provided by the Mode S sensor.

The outputs shall not be affected when a redundant Mode S channel is disabled.

4) ASR-9 only Mode - The ASR-9 is operational and the Mode S is disabled. Outputs from the SDS shall be radar only reports provided by the ASR-9.

(d) Analyze and report any degradation in the Mode S performance found during the testing described in a through c.

4.3.8.2 ARTS IIA Interface tests.- The contractor shall conduct formal tests to verify the proper operation of the Mode S sensor with the ARTS IIA system which is described in FAA-E-2570B. These tests shall be conducted using both a complete Mode S sensor and a complete ARTS IIA system including a Digital Data Acquisition System (DDAS) video processor, Random Access Display Subsystem (RADS), and all ARTS IIA modifications (software and hardware) required for integration with the Mode S sensor. The tests shall consist of at least the following:

(a) The verification of the physical, electrical and protocol compatibility of surveillance data and status from the Mode S sensor to the ARTS IIA. Simulated traffic scenarios shall be used which exercise all elements of the protocol and data configurations used in the Mode S to ARTS IIA interface as defined in FAA-RD-80-14A. All defined fields internal to the messages transferred between the systems shall be manipulated by the target scenarios such that all valid state of each field are verified to produce correct operation when received by the ARTS IIA. Capacity traffic loading shall also be tested at both the ARTS IIA limit (as defined in FAA-E-2570B section 3.10 and 3.11) and the Mode S limit.

(b) The verification of surveillance characteristics of the ARTS IIA while using Mode S surveillance data as its input source. These tests shall characterize the quality of the data provided to ATC by the ARTS IIA and identify any degradation or enhancement of the data relative to that which was provided by Mode S.

(c) The verification of the proper operation of the Mode S sensor with the ARTS IIA system during the prescribed equipment configurations which result from equipment failure in either system. Each failure mode shall be tested to verify the correct routing of data, equipment functional performance and information provided to ATC. As a minimum the following failure modes shall be tested to verify compliance with the equipment of FAA-2716 items (a), (c), (e), (f) of section 3.9.2.1:

- 1) automatic Mode S channel switchover
- 2) manual Mode S channel switchover
- 3) Mode S ATCBI Backup mode
- 4) ARTS IIA processor failure
- 5) surveillance data path failure

4.4 Software test requirements

4.4.1 Informal software testing.- The contractor shall conduct informal software testing in accordance with the requirements of 4.4.1.1. and 4.4.1.2 for all Mode S system software developed. Formal testing shall be conducted in accordance with 4.4.2. The Government shall have access to all informal test information and results.

4.4.1.1. Module (unit) tests.- Prior to start of preliminary qualification tests (PQTs) the contractor shall conduct (informal) module level tests. For each module, the contractor shall maintain a unit test folder which shall contain, as a minimum, a description of each specific Mode S program functional/performance requirement designed into the module, the objective of each test conducted, the test steps invoked, the test result(s) and the date each test was conducted. The tests shall be witnessed by software quality assurance (SQA) personnel and on conclusion of each test the SQA representative shall affix a SQA identification stamp and date on each test data sheet indicating that satisfactory/successful test results were achieved for each program functional/performance requirement identified.

4.4.1.2 Functional string test.- Prior to conducting formal qualification test (FQT) the contractor shall conduct (informal) tests of each functionally related string (e.g., path or threads) contained/defined within each computer program component (CPC). For each CPC the contractor shall maintain a test folder which shall contain, as a minimum, a description of the Mode S program performance/functional requirement(s) designed into the CPC, a description of each string contained therein, the objective of each test conducted, the test steps invoked, the tests results and the date each test was conducted. The tests shall be witnessed by SQA personnel and on conclusion of each test the SQA representative shall affix a SQA identification stamp and the date on each test data sheet indicating that satisfactory/successful test results were achieved for each program functional/performance requirement identified.

4.4.2 Formal software testing.- The contractor shall conduct formal software testing in accordance with the requirements of 4.4.2.1 and 4.4.2.2 for all Mode S software developed, using Government approved software test plans and software test procedures (reference 3.13.1.2.5.5) and 3.13.1.2.5.6). The contractor shall document the results of formal software testing in software test reports (reference 3.13.1.2.5.7) and submit same to the Government for review and approval. The Government shall be invited to witness all formal software testing.

4.4.2.1 Preliminary qualification testing (PQT).- The contractor shall conduct PQT for each CPCI in accordance with the requirements specified in 4.3 of the respective software top level design document (reference DOT/FAA/PM-83/37, Part 2).

4.4.2.2 Formal qualification testing (FQT).- The contractor shall conduct FQT for each CPCI in accordance with the requirements specified in 4.4 of the respective software top level design document (reference DOT/FAA/PM-83/37, Part 2).

4.4.2.3 Hardware-software integration testing (HSIT).- Subsequent to FQT, the contractor shall conduct HSIT in order to demonstrate that the CPCI's when integrated with the using CI's perform and meet the requirements of this specification, to the maximum extent possible in the contractor's facility.

4.5 Sensor hardware software integration testing (Sensor HSIT).- The contractor shall conduct a sensor level test to verify that the complete Mode S sensor hardware (CIs) and software (CPCIs) are properly integrated. This test shall verify all interfaces between the CIs and CPCIs which comprise the sensor. Requirements verified at a lower level HSIT need not be re-verified at the system level HSIT. This test shall verify that the data and control information are properly exchanged between CIs using the Mode S functionally qualified software. The CPCIs used in system integration testing must have completed FQT and the hardware CIs must have completed CI acceptance testing described in the CI ATP. The CI level hardware software integration (4.4.2.3) must be complete for all CIs and CPCIs prior to initiation of sensor hardware software integration. The CIs and CPCIs which comprise the sensor for sensor HSIT are as follows:

- Transaction Processing CPCI
- Monitoring CPCI
- Data Extraction CPCI
- Executive CPCI
- I/O Firmware CPCI
- Reply-to-Reply Processing CPCI
- Interrogator Performance Monitor CPCI
- Interrogator CI
- DPS CI

This space intentionally unused.

- (m) A buffer providing the interface between both ATCRBS and Mode S track update and the radar track update function shall exist for beacon tracks that have exceeded the radar substitution timeout limit. The radar track update function will include the track number into the appropriate track list, just as if it were a track initiation. The interface buffer will be monitored in the same manner as the radar track initiation file. Before entry is made into the radar track lists, the data of the beacon track will be modified to reflect the normal data of radar track. Entry into the radar track lists will be made immediately upon receipt in the interface buffer. This will provide for dissemination for the next scan radar report as correlating to a radar track, with no interruption of disseminated data.

40.3.3.8 Surveillance transmit.- The surveillance transmit function shall handle weather reports that have been placed in the radar surveillance transmit output file by the radar input processor function. Weather reports have no time-in-storage field and shall be handled as a map or status message and discarded if older than the value prescribed for discard of radar reports. Surveillance transmit controls the transfers of this weather data from the Mode S sensor to appropriate ATC facilities as specified by current dissemination rules (site adaptable).

40.3.3.9 Performance monitor.- The performance monitor function of the Mode S sensor shall be modified to allow monitoring of the radar interface. Status information from the radar that are passed to the Mode S sensor via the interface card shall be monitored.

40.3.3.9.1 Functional requirements.- A primary function of the Mode S performance monitor function is the handling of error conditions reported via interface boards. Since the radar interface to the Mode S system will be implemented using a Mode S interface board, the performance monitor function shall be modified to accommodate an additional interface board.

The performance monitor decision tables shall be expanded to include the status information associated with the interface. "Countable" faults and fatal faults shall be reported as per status processing associated with other interfaces of this type.

Additional status codes and messages shall be defined for the status associated with the interface. These status codes shall also be added to the maintenance display (3.3.10). Definition of the status associated with the radar interface shall be approved during design review.

In addition to status codes associated with the interface, the performance monitor function shall transmit a yellow status condition when the current count of active radar tracks has reached the system maximum.

FAA-E-2716

-486-

This page intentionally unused.

FAA-E-2716
APPENDIX I

-I-1-

APPENDIX I

MODE SELECT BEACON SYSTEM (MODE S) SENSOR

LIST OF ABBREVIATIONS AND ACRONYMS

LIST OF ABBREVIATIONS AND ACRONYMS

Note: Abbreviations designating fields and subfields of the Mode S Interrogation and reply formats are given in the Mode S National Standard.

<u>Abbrev.;</u> <u>Acronym</u>	<u>Meaning</u>	<u>Abbrev.;</u> <u>Acronym</u>	<u>Meaning</u>
AA	Aircraft Address	A/P	Address/Parity
AARTU	Antenna Azimuth-Range-Timing Unit	APG	Azimuth Pulse Generator
AC	Air Carrier	APWR	ATCRBS Interrogation Power (parameter)
ACF	Active Control Flag (bit)	ARIES	Aircraft Reply and Interference Environment Simulator
ACI	Azimuth Completion Indicator	ARP	Azimuth Reference Pulse
ACK	Pilot Acknowledgement Request	ARSR	Air Route Surveillance Radar
ACP	Azimuth Change Pulse	ARTS	Automated Radar Terminal System
A/D	Analog to Digital	ASR	Airport Surveillance Radar
ADCCP	Advanced Data Communication Control Procedure	AT	Available Time (Code)
AF	Active Flag (bit)	ATC	Air Traffic Control
ADCOMM	Air Defense Command	ATCRBS	Air Traffic Control Radar Beacon System
AI	Altitude/Identity Designator (Code)	ATL	Active Target List
AIMS	ATCRBS Improved Mark XII System	Au	Azimuth Unit
ALRL	Active List Range Length (Parameter)	AZ	Azimuth Measurement Command (bit)
ALT	Altitude (Mode C)	AZE	Azimuth to End (at a reflecting surface)

FAA-E-2716
APPENDIX I

-I-3-

<u>Abbrev.; Acronym</u>	<u>Meaning</u>	<u>Abbrev.; Acronym</u>	<u>Meaning</u>
AZS	Azimuth to Start (at a reflecting Surface)	CONUS	Continental United States
BCD	Binary Coded Decimal	CPCI	Computer Program Configuration Item
BDS	B-Definition Subfield	CPME	Calibration and Performance Monitoring Equipment
BF	Boresite Flag (bit)	CPU	Central Processor Unit
CA	Capability	CRT	Cathode Ray Tube
CALT	Mode C Altitude Confidence (word)	CSF	Connected Sensor Flag
CAC	Chip Amplitude Comparison	CT	Uplink ELM Channel Time
CAP	Capability Request Flag	CTR	Counter
CB	Clear-B	CTSL	Counts, Long (system parameter)
CBN	Clear-B, Normal protocol	CTSS	Counts, Short (system parameter)
CCA	Circuit Card Assembly	CTT	Cycle Test Time
CCA	Collimation Correction Angle	DAAT	Duplicate Address Alert Table
CCN	Clear C, Normal protocol	DABS	Discrete Address Beacon System
CCR	Collimation Correction Range	dB	Decibels
CD	Common Digitizer	dBm	Decibels, with respect to 1-milliwatt power level.
CDN	Clear-D, normal protocol	DCOUNT	Comm-D Message Counter
CFLAG	Mode C Code Confidence (word)	DDS	D-Definition Subfield
CFAR	Constant False Alarm Rate	DELM	Downlink Extended Length Message (transaction)
CIP	Coordination In Progress (flag)	DF	Downlink Format Field
Comm-N	Communication Message Format (A,B,C, or D type)	DI	Delivered/Expired Indication

<u>Abbrev.;</u> <u>Acronym</u>	<u>Meaning</u>	<u>Abbrev.;</u> <u>Acronym</u>	<u>Meaning</u>
DIP	Dual Inline Package	INTL	Interrogation Length
DL	Mode S Lockout (bit)	I/O	Input/Output
DLM	Mode S Lockout Management	ILL	Interrogation Length, Long
DPSK	Differential Phase-Shift Keyed	ILS	Interrogation Length, Short
DR	Downlink Request	IQ	Coverage Map Call Index
ELM	Extended Length Message	IR	Interrogation Request (netted surveillance)
EXP	Time to Expire	ISLS	Interrogation Sidelobe Suppression
EXTBL	Track Data Parameter	JSS	Joint Surveillance Site
FO	Processor Overload flag (bit)	L	Variable Used in Roll-Call Scheduling
FS	Flight Status	LC	Lock Count
GA	General Aviation	LCS	Lockout Control State
GFE	Government Furnished Equipment	LD	Lockout Duration
HOL	Higher Order Language	LDM	Lockout Duration, Maximum
HYTIME	High Power Interrogate Time (parameter)	LOS	Line of Sight
ICAO	International Civil Aviation Organization	LRU	Lowest Replaceable Unit
ICD	Interface Control Document	LSB	Least Significant Bit
ID	Identity	MA	Comm-A Message text (56 bits)
IDS	Identifier Designator Subfield	MB	Comm-B Message text
IF	Intermediate Frequency	MBH	Mainbeam High (monopulse off boresite parameter)
IFR	Instrument Flying Rules		
II	Interrogator Identification		

<u>Abbrev. ;</u> <u>Acronym</u>	<u>Meaning</u>
MBL	Mainbeam Low (monopulse off boresite parameter)
MBRT	Mean Bench Repair Time
Mb/S	Megabits/Second
MC	Unit of ELM Data Field (80 bits)
MCU	Modulation Control Unit
MESS	Interrogation Message
MNAS	Maximum Number of Assigned Sensors
MODE S	Mode Select
MPS	Maintenance Processor Subsystem
MSB	Most Significant Bit
MTD	Moving Target Detector
MTI	Moving Target Indicat(or) (ion)
MTL	Minimum Threshold Level
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
MUSL	Minimum Usable Mode S Signal Level
NAS	National Airspace System
NC	Number of C-Segment
NCT	Normal Channel Time

<u>Abbrev. ;</u> <u>Acronym</u>	<u>Meaning</u>
ND	Number of D-Segment
non-ATC	A ground user of the sensor other than ATC, this is the WCP
NRZ	Non Return to Zero
NSEG	No. of ELM Segments
OEC	Outlist Expiration Counter
OECT	Outlist Expiration Counter Threshold
OSE	Outlist Entry Flag (bit)
OT	Overhead Time
OTP	Overhead Time Parameter
P	High Power Flag (bit) or Message Priority
PAM	Pulse Amplitude Modulation
PC	Protocol
PCA	Positive Control Area
PCT	Priority Channel Time
PERT	Program Evaluation Review Technique
PPCB	Power Programming Control Bit
PPI	Plan Position Indicator
PRF	Pulse Repetition Frequency
PR	Probability of Reply

Abbrev. ; <u>Acronym</u>	<u>Meaning</u>	Abbrev. ; <u>Acronym</u>	<u>Meaning</u>
PRI	Pulse Repetition Interval	RDAS	Radar Data Acquisition System
PS	Priority Status	RDEL	Range Delay
PSF	Programming Support Facility	RDT	Downlink ELM Reply Spacing
PTRIG	Pre-Trigger (System Parameter)	REPL	Reply Length
QSLSA	Quantized Sidelobe Suppressed ATCRBS	RF	Radio Frequency
Q Σ NS	Quantized Sum Channel Negative Slope	RGD	Range Guard
Q Σ PS	Quantized Sum Channel Positive Slope	RL	Reply Length
QSLSD	Quantized Sidelobe Suppressed Mode S	RLL	Reply Length, Long
Q Σ A	Quantized Sum Channel ATCRBS Signal	RLS	Reply Length, Short
Q Σ D	Quantized Sum Channel Mode S Signal	RMMS	Remote Maintenance Monitoring System
Q Σ SNS	Quantized Sum Channel Negative Slope	RMS	Remote Maintenance Subsystem
Q Σ SPS	Quantized Sum Channel Positive Slope	ROCC	Radar Operations Control Center
RAM	Random Access Memory	RPR	Repetition Period (downlink ELM Replies)
RBM	Reserve B, Multisite	RR	Remote Sensor Request bit
RC	Reply Type Code	RRP	Repetition Rate Period
RCM	Reserve C, Multisite	RSLS	Receive Sidelobe Suppression
RCOR	Range Correction	RSS	Comm-B Reservation Status Request
RD	Range Delay (first target)	RT	Round Trip or Residual Time
		RTC	Reply Type Code
		RTL	Released Target List

<u>Abbrev. ;</u> <u>Acronym</u>	<u>Meaning</u>	<u>Abbrev. ;</u> <u>Acronym</u>	<u>Meaning</u>
RTN	Return (flow diagram symbol)	SQRT	Square Root (function)
RTQC	Real Time Quality Control	SQ Σ D	Stream of Quantized Sum Channel Mode S (signals; VPQ output)
Ru	Range Unit	SRAP	Sensor Receiver and Processor
RZC	Radar Zenith Cone	SS	Schedule Start Time (code)
SC	Segment Count	SSF	System Support Facility
SCAN	Antenna Scan Rate (parameter)	STC	Sensitivity Time Control
SD	Special Designator	STCA	STC Waveform (ATCRBS)
SET	Interrogation Transmit Time Plus 800	STCD	STC Waveform (Mode S)
SFN	Surveillance File Number	TATF	Terminal Automation Test Facility
SIG	Offboresight Signal plus table offset value	TCA	Terminal Control Area
SIR	Signal-to-Interface Ratio	TCAS	Traffic Alert and Collision Avoidance System
SL	Schedule Limit	TCI	Traffic Completion Indicator
SLS	Sidelobe Suppression	THETAHALF	Half Beamwidth (parameter)
SLSF	Sidelobe Suppression Flag	TMS	Tactical Message Subfield
SMA	Single/Multiple Designator	TOD	Time of Day
SMF	Special Mode Flag	TOY	Time of Year
SNR	Signal-to-Noise Ratio	TR	Track Record
SPI	Special Identity (pulse)	TRACON	Terminal Radar Control
SPIC	Special Identity (pulse) Confidence (bit)	TRD	Transponder Reply Delay
SQ ϕ	Monopulse Digitizer Output (signal)	TRIGW	Trigger Window (system parameter)

Abbrev.;

AcronymMeaning

TRR	Request for data; based on poor track quality
TTG	Test Target Generator
TTP	Transmission Time Pulse
UC	Control Status
UD	Unlock Duration
UDM	Unlock Duration Maximum
UEI	Uplink ELM Indicator (parameter)
ULC	Unlock Count
UMF	Utility Message Flag
USF	Unconnected Sensor Flag
UTC	Universal Time Clock
VFR	Visual Flight Rules
VPQ	Video Pulse Quantizer
WCP	Weather Communications Processor, this is the sensor's non-ATC user
X	X-Bit (ATCRBS Code)
ZCTHR	Zenith Cone Range (parameter)

FAA-E-2716
APPENDIX II

-II-1-

APPENDIX II

MODE SELECT BEACON SYSTEM SENSOR

SUPPORT FACILITIES

APPENDIX II

MODE SELECT BEACON SYSTEM SENSOR

SUPPORT FACILITIES

20.1. SCOPE

20.1.1 Scope.- This appendix specifies the requirements for Mode S sensor support facilities. These facilities are necessary to provide for the maintenance, modification, and debugging of sensor software at a central location, and to provide regional facilities for analyzing and adjusting sensor performance (including the insertion and modification of sensor site adaptation parameters, changing of coverage, dissemination, and reflection zones and areas, etc.).

20.1.2 Classification.- Two types of Mode S sensor support facilities differing in purpose and configuration are covered by this specification appendix.

20.2.1 Type.- A Mode S sensor support facility shall be of one of the following types:

Type I - Programming Support Facility (PSF). The programming support facility (PSF) shall include equipment and supporting software needed in the maintenance and debugging of the sensor programs. A complete operating sensor is assumed to be available to the users of the PSF. The equipment provided shall be appropriate for software maintenance and analysis tasks. The location and number of the PSFs shall be as specified in the contract schedule.

The PSF shall be independent of the Mode S sensor. However, the processor used shall be compatible with those used in the sensor so that the sensor programs may be run for test and debugging purposes on the PSF processors. It is not required that multiprocessor debugging be supported by the PSF alone, but it shall supply debugging aids for performing such tests on the sensor itself.

Type II - Sensor Support Facility (SSF). The sensor support facility (SSF) shall provide a regional capability to analyze sensor performance (via data recorded during sensor operation), and to modify site adaptation parameters so as to meet changing operational needs. The SSF shall be provided with a capability to generate site adapted functional programs from the master program and site unique adaptation parameters and shall be capable of maintaining a copy of the site adaptation parameters and functional program for each sensor with which it is associated. The number and location of the SSFs will be specified in the contract schedule.

20.2. DEFINITIONS None.

20.3. REQUIREMENTS

The contract shall deliver support facilities in the type and quantities required by the contract schedule. The support equipment shall be in accordance with the requirements specified herein; equivalent tools used by the contractor in developing the Mode S operational and support computer programs may be provided.

20.3.1 Central Processor.- Each Type I or Type II support facility shall include a processor(s) of sufficient memory and power such that each simultaneous user may perform text editing, program assembly or compilation, or linking and loading of programs appropriate to sensor software maintenance or performance analysis without restriction. User program execution shall also be unrestricted as long as the system resources required do not exceed the resources used by the editor, assembler, compiler or linking loader. The processor for the Type I and Type II support facilities shall be identical.

20.3.2 Input/output hardware.- The following I/O devices shall be provided in the quantities noted for each type of facility. Each device shall be connected to processor(s) and memory and supported by software capable of providing a simultaneous user interactive programming environment:

	<u>Quantity</u>	
	<u>Type I</u>	<u>Type II</u>
(a) Interactive graphics CRT terminals with light pen, graphics mouse, or tablet digitizer capabilities, and interfaced such that data	2	2

is transferred at a rate of at least 1000 characters per second. These terminals shall be appropriate for the entry, generation, and display of maps and reflection zones and areas. The contractor shall determine the detailed design requirements for this terminal.

	<u>Quantity</u>	
	<u>Type I</u>	<u>Type II</u>
(b) Video display terminals capable of displaying at least 10 lines of 80 characters each, and interfaced such that data is transferred at least at a rate of 1000 characters per second.	4	2
(c) Magnetic tape unit: 1/2 inch tape, 1600 bpi, transfer rate at least 60000 bytes per second, 2400 foot reel capacity.	2	2
(d) Multi-platter disk drive and controller, with: Moving head disk, Interchangeable disk packs, 25,000,000 16-bit words/disk pack, minimum, and 30 ms average access time, maximum	2	2
(e) Line printer: 120 columns/line, minimum, 300 lines/minute, minimum.	1	1

20.3.3 Software requirements.- The following support software shall be provided with each PSF or SSF:

- (a) Monitor system,
- (b) Symbolic assembler,
- (c) Higher level language compiler,
- (d) Linking loader,
- (e) Text editor,
- (f) Source library and executable module library update utilities,
- (g) Mathematical subroutine library,
- (h) Debugging aids (PSF only),
- (i) Data retrieval aids,
- (j) Quick look analysis,
- (k) Data Communications (to/from sensor) utility

20.3.3.1 Monitor system.- The monitor system shall support the multi-user interactive programming environment described above, a disk file system, and input/output operations to all devices attached to the PSF or SSF.

20.3.3.2 Symbolic assembler.- The symbolic assembler shall provide all facilities necessary for definition of programs and data storage on the PSF and SSF systems. It shall provide any specialized facilities that may be required for ease of programming for the particular equipment and system architecture of the sensors. It shall have a macro definition facility, and shall produce relocateable program modules.

20.3.3.3 Higher level compiler.- The higher level language compiler shall be suitable for scientific and data analysis programming on the program development system. It shall produce relocateable program modules.

20.3.3.4 Linking loader.- The linking loader shall link together relocateable modules produced by either the assembler or the compiler into executable load modules. It shall provide any specialized facilities which may be necessary to link modules for execution in the sensor's processors, where data references must be resolved appropriately to either local or global memory.

20.3.3.5 Text editor.- The text editor shall provide an interactive editing environment suitable for entering and editing program source text for the assembler or compiler, and also suitable for English text editing for documentation purposes.

20.3.3.6 Source library and program module library update utilities.- These library update utilities shall provide for the creation and updating of source code libraries and program module libraries. They shall provide for control over these updates and logging mechanisms suitable for supporting software configuration control. It shall be possible to simultaneously maintain several versions of a software system.

20.3.3.7 Mathematical subroutine library.- This library shall include the standard mathematical and statistical subroutines, including but not limited to the trigonometric, square root, logarithmic, and exponential functions. The routines shall be callable from either assembly language or the higher level language provided.

20.3.3.8 Debugging aids.- Debugging aids shall be provided for debugging sensor programs on the PSF. Features, including hardware and software, necessary to perform interactive debugging on an executing, real time multiprocessor system shall be provided. This may require the support of specialized debugging hardware and software added to the sensor. At least the following minimum capabilities shall be provided:

- (a) Reading and modifying words in local or global memory.
- (b) Reading and modifying hardware registers where these are accessible to the software.
- (c) Dumping blocks of local or global memory to the line printers.

- (d) Masked memory search for particular word values in local or global memory.
- (e) Setting and clearing breakpoints at which trace information will be taken and dumped to line printer or tape or displayed on a video terminal.
- (f) Loading of programs from disk or magnetic tape, and transferring of programs and data between local and global memory.

20.3.3.9 Data retrieval aids.- Programs shall be provided to simplify the accessing of data recorded on magnetic tape by Mode S sensors in real time operation. These shall provide an interface between the higher level language and the basic tape reading operations, specialized to the task of data retrieval for analysis purposes. The retrieval programs shall be accessed via subroutine call. The data passed as arguments to this call shall allow the specification of conditions a data block must satisfy for retrieval. It shall be possible to specify that certain types of data blocks are to be retrieved and/or that certain fields are to have specified values or lie between specified limits. It shall be possible to reference fields by symbolic name, and data block types by either symbolic name or number. The call shall return the first block satisfying the specified condition found in a sequential search of the data tape. The search shall begin at the point where the last search command terminated, or the beginning of tape if the tape has just been loaded or rewound.

If not provided by the higher level language, facilities shall also be provided for accessing by symbolic name the fields of the data records retrieved by the search command, including masking and shifting that may be required to unpack these fields.

20.3.3.10 Data communications utility.- A software utility shall be provided to support the data communications link described in 3.3.3.5 and 3.5.5 in the main body of this specification. In the PSFs this software utility shall provide for the simultaneous interchange of data with a minimum of four PSF or sensor sites. In the SSFs this software utility shall provide for the simultaneous interchange of data with a minimum of three sensor sites and the PSF.

20.3.4 Interface requirements.

20.3.4.1 Program support facility interface requirements.- The PSF shall be capable of transmitting or receiving data to/from any SSF or sensor site over the data communications link described in 3.5.5 of the body of this specification. This communications capability shall provide for a minimum of four simultaneous circuit connections.

20.3.4.2 Sensor support facility interface requirements.- Each SSF shall be capable of transmitting or receiving data to/from any of the sensor sites with which it is associated, and the PSF, over the data communications link described in 3.5.5 of the body of this specification. This communications capability shall provide for a minimum of four simultaneous circuit connections (3 sensor sites and the PSF or 4 sensor sites).

This space intentionally unused.

FAA-E-2716
APPENDIX II

-II-8-
(last page of Appendix II)

This page intentionally unused.

FAA-E-2716
APPENDIX III

-III-1-

APPENDIX III

MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR OPERATION WITH BACK-TO-BACK ANTENNA

APPENDIX III

MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR OPERATION WITH BACK-TO-BACK ANTENNA

30.1. SCOPE AND PURPOSE

30.1.1 Scope.- This section specifies additional Mode S sensor requirements to provide the capability of operating with a back-to-back antenna. The antenna consists of two faces as specified in FAA-ER-240-35b, configured as specified in FAA-ER-240-35a.

30.1.2 Purpose.- The purpose of this sensor configuration is to obtain twice the data rate normally available with a single face antenna. This higher data rate is required to support future air traffic control automation systems.

30.2. DEFINITIONS

30.2.1 Back-to-back antenna.- This antenna is defined as a single antenna system rotating on one pedestal. It has the capability of operating with two beams formed by two faces that are separated by a nominal 180 degrees. The rotating joint used with this antenna system will have provision for independent sum, difference and SLS control channels for each face.

30.2.2 Front and back faces.- When operated in conjunction with a radar, the face shared with (or pointing in the same direction as) the radar is termed the front face and the other the back face. In this case the antenna azimuth register indicates the nominal boresight of the radar and front face.

When operated in a beacon-only mode, the face whose nominal boresight is indicated by the antenna azimuth register is termed the front face.

30.2.3 Antenna scan time.- Unless otherwise qualified, all references to the antenna scan time for the back-to-back sensor shall be understood to mean one-half the scan time of a single face antenna rotating at the same rate.

30.3. REQUIREMENTS

Note: The following requirements are based upon the use of a separate front end subsystem for each antenna face. Other implementations that use digital switching to share some of the elements between the antenna faces, and/or use two separate identical channels (as specified in 3.7 of the main body of this specification), may be used.

30.3.1 Design requirements.- Unless otherwise specified in this appendix, the back-to-back sensor shall meet all of the requirements specified in the main body of this document.

30.3.2 Performance requirements.

30.3.2.1 Capacity.- The capacity requirements of the back-to-back sensor shall be the same as for the basic Mode S sensor as specified in 3.3.2.5 of the main body of this document. The services specified therein shall be provided at the scan rate of the back-to-back antenna.

30.3.2.2 Data delays.- Data delays for the scan-to-scan processor shall be the same as specified in 3.3.2.6 of the main body of this specification.

30.3.3 Sensor functions.- A block diagram of the front end of the back-to-back sensor is shown in fig. III-1.

30.3.3.1 Overall operation.- The back-to-back sensor shall operate with two separate front end subsystems each connected to an antenna face through a rotary joint containing 6 beacon channels as illustrated in fig. III-1. The remainder of the sensor functions shall operate in a time-shared arrangement wherein the sensor transmits or receives from at most one of the antenna faces at any moment. Channel management shall keep track of the two wedges of visibility (as shown in Fig. III-2) and shall schedule Mode S and ATCRBS interrogations as required via the appropriate front end subsystem and its associated antenna face.

Separate off-boresight lookup tables shall be maintained for each of the interrogator-processor subsystems including each antenna face. This shall include off-boresight look-up tables such that a spare interrogator-processor, when enabled, can immediately operate with either antenna face. Therefore replies must be tagged with face and interrogator-processor channel in order to permit conversion to off-boresight angle with the proper lookup table.

Surveillance processing shall operate on $11-1/4^\circ$ sectors in a two-pass operation. The pass for the front face shall be exactly as specified in the main body of this document, section 3.4.6. The pass for the back face shall be the same, except that all tasks related to radar processing shall be omitted. Performance monitoring shall make separate surveillance checks for each face and initiate recalibration as required. The remaining scan-to-scan processing functions shall operate on both front and back sector targets and perform all of the tasks as specified for that function in 3.4 of the main body of this document.

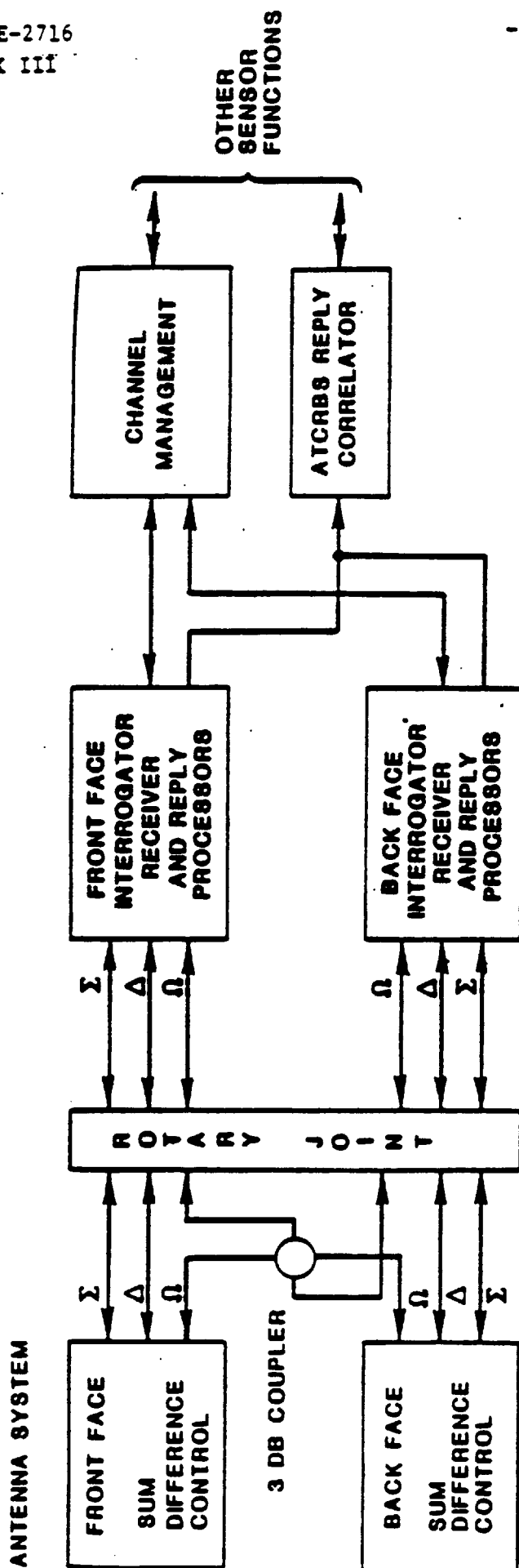


FIG. III-1. FUNCTIONAL BLOCK DIAGRAM OF THE FRONT END OF A MODE S EN-ROUTE SENSOR

AA-E-2716
JAN 111

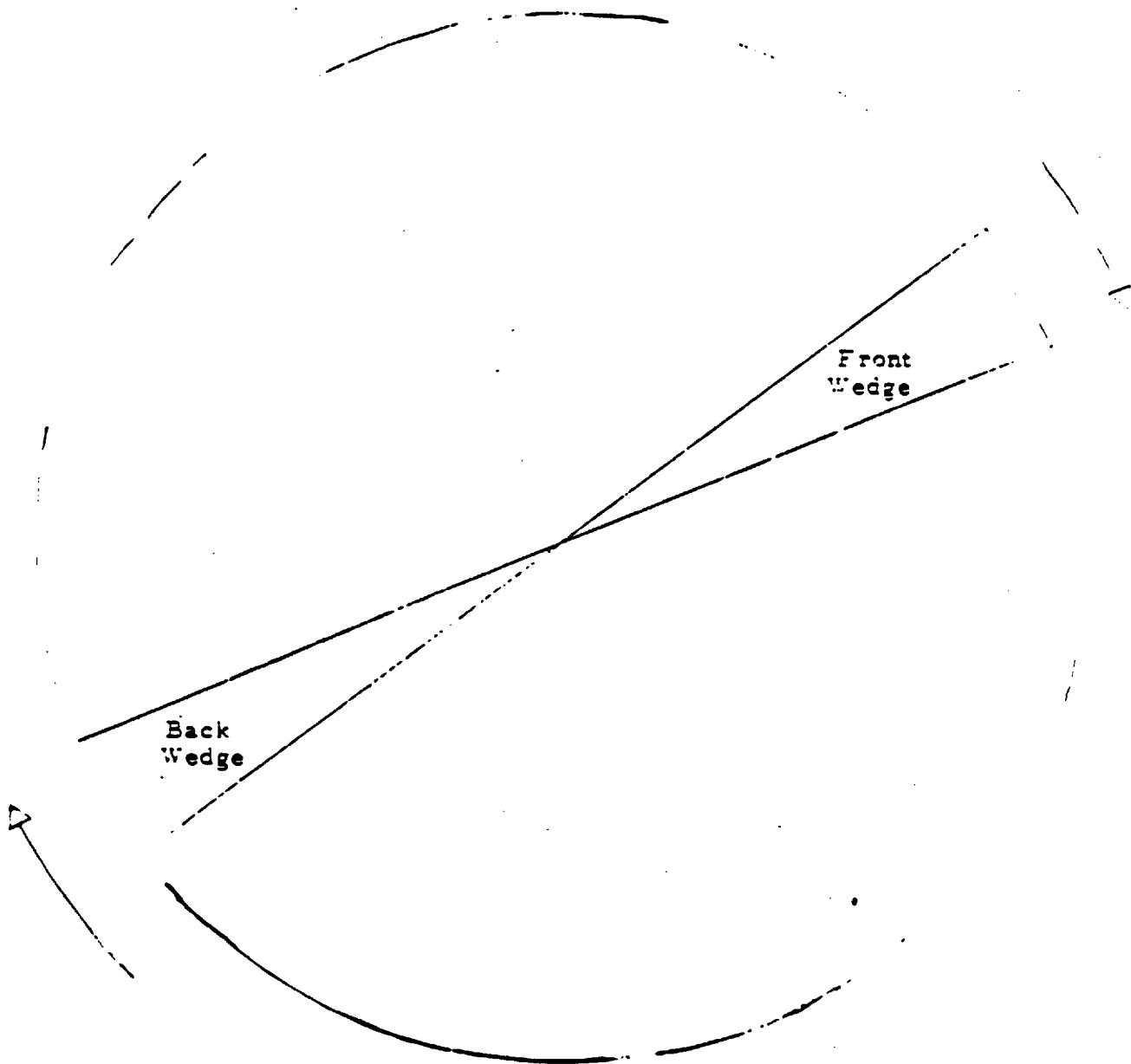


FIGURE III-2

BACK-TO-BACK COVERAGE WEDGES

30.3.4 Functional design requirements.- The following subparagraphs describe the details of the modifications required to support back-to-back sensor operation. The order of presentation follows that of 3.4 of the main body of this document, and unless otherwise specified, all of the requirements of the main body apply to the back-to-back sensor. Where specification conflicts occur, this appendix shall take precedence over the parent specification.

30.3.4.1 Channel management.

30.3.4.1.1 Overview.- The organization of channel management into five sub-functions is not affected by this appendix; however, two active target lists shall be maintained and all target records shall contain a bit identifying the antenna face to be used to communicate with the target. The two active target lists shall be used to form separate schedules for each antenna face. The lists of targets released from each beam may be merged, so long as the antenna face bit is preserved.

30.3.4.1.2 Channel control.-Channel control shall accept a frame table suitable for back-to-back operation. The ATRBS periods in such a frame table shall contain an identifier of which antenna face is to be used. The number of front-face ATRBS periods in a frame shall equal the number of back-face ATRBS periods in that frame. ATRBS operation through each face shall follow identical procedures for mode sequencing and transmission type. Channel control shall use the radar range mask to compute listening periods appropriate to the pointing directions of the two antenna faces, each of which shall be predicted by channel control as required. ATRBS interrogation control commands shall contain a bit designating the antenna face to be used for transmission.

Channel control shall compute two new azimuth limits and two cutoff azimuths for each Mode S period. One set of azimuths shall be appropriate for each antenna face. The new azimuth limits shall be included in the enabling command to transaction preparation. The cutoff azimuths shall be included in the enabling command to target list update.

Channel control shall compute available time and activate roll-call scheduling and transaction update exactly as specified for a single beam antenna.

30.3.4.1.3 Transaction preparation.- When activated by channel control, transaction preparation shall fetch two groups of targets from the surveillance file, one group for each new azimuth limit. The two lists shall be kept separate, and target transaction blocks shall be prepared for each target, exactly as specified in the body of this specification, except for the addition of an antenna face bit to each target record. The two groups of target transaction blocks shall be identified and placed in the transaction buffer so that either group may be identified by target list update.

30.3.4.1.4 Target list update.- When activated by channel control, target list update shall modify each of the active target lists, exactly as specified in the body of this specification. The target transaction blocks for front-face targets shall be merged into the front-face active target list, and similarly for the back-face list. The two sets of released targets may be merged or maintained in separate lists. Each active target list header shall be updated as specified in the specification.

30.3.4.1.5 Roll-call scheduling.- When activated by channel control, roll-call scheduling shall perform an allocation computation, using both active target lists. With a single antenna beam, available channel time is allocated among the five allocation classes by exhausting the targets of an allocation class before moving on to the next lower allocation class in priority. With back-to-back antenna beams, there shall be ten allocation classes, ranked in priority as follows:

- (a) Allocation class one of the front-face active target list.
- (b) Allocation class one of the back-face active target list.
- (c) Allocation class two of the front-face active target list.
- (d) Allocation class two of the back-face active target list.
- (e) Allocation class three of the front-face active target list.
- (f) Allocation class three of the back-face active target list.
- (g) Allocation class four of the front-face active target list.
- (h) Allocation class four of the back-face active target list.
- (i) Allocation class five of the front-face active target list.
- (j) Allocation class five of the back-face active target list.

Available channel time shall be allocated and targets qualified for scheduling by exhausting the ten allocation classes in the above-listed order, in exact analogy to the algorithm specified for a single beam.

If any targets in the front-face active target list are qualified for scheduling, roll-call scheduling shall produce a schedule for these targets, starting at the assigned schedule start time, exactly as specified in the body of this specification. If targets in the back-face active target list are qualified for scheduling, a second roll-call schedule shall be produced for these targets. All interrogation control commands shall contain a bit indicating the antenna face to be used. During a Mode S period, this bit will change, at most, once for each roll-call schedule.

30.3.4.1.6 Transaction update.- When activated by channel control, transaction update shall appraise replies from the schedule or schedules just produced, and it shall update the two active target lists, exactly as specified in the body of this specification.

30.3.4.2 Transmitter/modulation control.- Provision shall be made to send only front-face transmission control blocks to the front-face Interrogator and only back-face control blocks to the back-face Interrogator.

30.3.4.3 Multichannel receivers.- There are no functional changes within the multichannel receivers associated with operation with back-to-back antennas.

30.3.4.4 Mode S processing.- Provision shall be made to associate the proper antenna with each reply reported. No other changes are required in Mode S processing for operation with back-to-back antennas.

The antenna azimuth register shall indicate, as with single antenna operation, the boresight azimuth of the front antenna. Target azimuth determination for replies received on the back antenna shall be made via the separate monopulse lookup table provided for the back antenna, which will include the fixed offset of the back antenna boresight relative to the front antenna boresight.

30.3.4.5 ATCRBS processing.- Provision shall be made to associate the proper antenna in each reply block reported by the reply correlation function.

Target azimuth determination of replies received on the back antenna shall be made via the separate monopulse lookup table provided for the back antenna, which will include the fixed offset of the back antenna boresight relative to the front antenna boresight.

30.3.4.6 Surveillance processing.- Surveillance processing for the back-to-back sensor shall be performed at least once per 11.25° sector per face. The operation for each sector shall consist of processing the surveillance data from each face in separate, independent phases. The value of k in all subparagraphs of 3.4.6.10.4.2 shall be set equal to 2.

30.3.4.6.1 Front-face processing.- This phase of operation shall utilize as input all of the front-face Mode S and ATCRBS reports, plus all of the radar reports appropriate for that sector. Each and every task described in 3.4.6 of the main body of this document shall be performed as specified therein except that the Mode S preprocessing function shall utilize the front-face off-boresight lookup table. In the ATC-BI back up mode, the front face shall be used.

30.3.4.6.2 Back-face processing.- This phase of operation shall use as input all of the back-face Mode S and ATCRBS reports. Each and every task described

in 3.4.6 of the main body of this document shall be performed as specified therein except that:

- (a) The Mode S preprocessing function shall utilize the back face off-bore-sight lookup table.
- (b) All tasks related to the processing of radar data shall be omitted.

30.3.4.6.3 Determination of τ in Region 3. - With the back-to-back antenna configuration, 3.4.6.10.4.2.4 and 3.4.6.10.4.2.5 need to be modified to compute τ , which in this case will be the next time that either face of the antenna will see the track. Note that in this appendix, τ is normalized to the time it takes the antenna to turn 180° . The cases in 3.4.6.10.4.2.4 shall be changed as follows to accommodate the back-to-back antenna operation.

Case 1. If $\dot{\theta}_T = 0$, then $\tau = 1$.

Case 2. Not used.

Case 3. Not used.

Case 4. If $\dot{\rho} \geq 0$ and $\dot{\theta}_T \neq 0$,

set $R = 1$ and $\tau_0 = 1$

and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

Case 5. If $\dot{\theta}_T > 0$ and $\lambda \geq 3/2$

set $R = 1$ and $\tau_0 = 1 + \frac{3/4}{\lambda}$

and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

Case 6. If $\dot{\theta}_T > 0$ and $1/2 \leq \lambda < 3/2$

set $R = 2$ and $\tau_0 = 2 - \lambda/3$

and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

Case 7. If $\dot{\theta}_T < 0$ and $\lambda \geq 1/2$,

set $R = 1$ and $\tau_0 = 1 - \frac{1/4}{\lambda}$

and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

Case 8. If $\theta_r < 0$ and $\lambda < 1/2$ and $\rho < 0$,
set $\bar{R} = 1$ and $\tau_o = 1 + \lambda$
and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

Case 9. If $\theta_r > 0$ and $\lambda < 1/2$ and $\rho < 0$,
set $\bar{R} = 1$ and $\tau_o = 1 - \lambda/3$
and solve equation in section
3.4.6.10.4.2.5 with $k = 2$.

30.3.4.6.4 Track data message processing.- This processing shall operate as specified in 3.4.6.11 of the body of this specification.

30.3.4.6.5 Surveillance data dissemination.- In addition to the capabilities specified in 3.4.6.14 of the main body of this document, it shall also be possible to designate each ATC user of the sensor as a "single face" or "double face" user:

- (a) Single face users shall receive surveillance data from the front face only.
- (b) Double face users shall receive surveillance data from both faces.

30.3.4.7 Data link processing.

30.3.4.7.1 Input processing.- Input processing shall operate as specified in 3.4.7.2 of the main body of this document.

30.3.4.7.2 Output processing.- Targets processed from the released target list may be in sequence by face or merged. Whichever order is used, the processing for each target shall be exactly as specified in 3.4.7.3 of the main body of this document.

30.3.4.8 Network management.- The network management function shall operate exactly as specified in 3.4.8 of the main body of this document.

30.3.4.10 Performance monitoring.

30.3.4.10.1 Overview.- Performance monitoring for the back-to-back sensor shall function in essentially the same manner as for the basic Mode S sensor as specified in 3.4.10 of the main body of this document. The major difference involves the separation of surveillance and calibration checks between each of the two front end and antenna paths.

30.3.4.10.2 Hardware monitors.- The hardware monitors for the back-to-back sensor shall be incorporated below the rotary joint, as shown in Fig. III-3. The monitoring function is the same as required for the basic Mode S sensor as specified in 3.4.10.2 of the main body of this document, except that provision shall be made to monitor any additional transmitters and receivers.

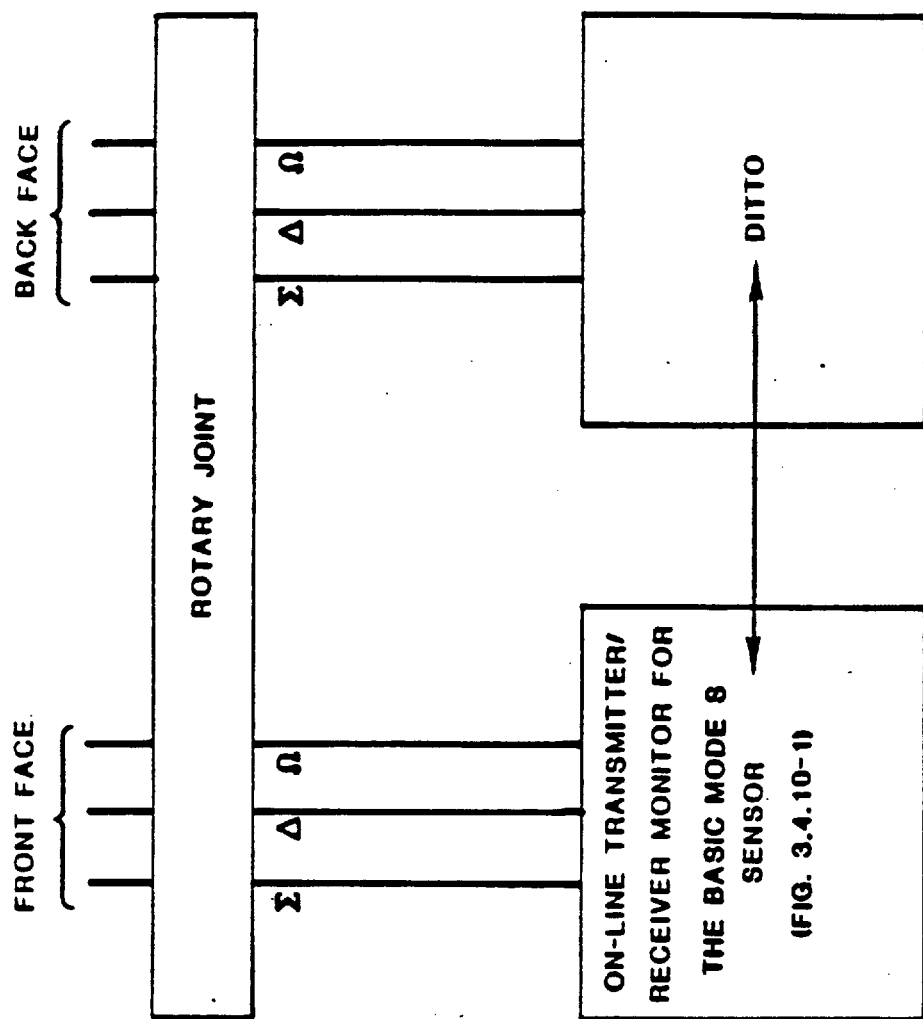


FIGURE III-3

ON-LINE TRANSMITTER/RECEIVER MONITOR BLOCK DIAGRAM FOR THE BACK-TO-BACK SENSOR

30.3.4.10.3 Checks performed using the CPME.- Checks related to the CPME tracks shall be conducted without regard to antenna face considerations. This includes steps 3.4.10.3.3.1, -5, -6 and -7 of the main body of this document. Checks related to surveillance measurements (3.4.10.3.3.2-4 of the main body of this document) shall be performed separately for each face.

30.3.4.10.4 Monopulse azimuth checks.- Each of the checks specified in 3.4.10.3.5.2 of the main body of this document shall be performed separately for each antenna face.

30.3.4.10.5 Decision algorithm.- The decision table for the back-to-back sensor shall include provision for monitoring the status of the surveillance and monopulse azimuth performance of each face independently. Provision shall be made in the sensor status message to specify the face when reporting the occurrence of a surveillance or monopulse error condition.

30.3.4.11 Sensor calibration.- The back-to-back Mode S sensor shall maintain separate off-boresight lookup tables for each antenna face and associated on-line front end. In addition, separate off-boresight lookup tables shall be maintained for the spare Integrator-Processor such that when enabled it can immediately operate with either antenna face. Each off-boresight lookup table and the procedures for their initial start-up and on-line calibration shall be the same as specified in 3.4.11 of the main body of this document except that:

- (a) Only front-face CPME replies shall be used for the front-face table, and
- (b) Only back-face CPME replies shall be used for the back-face table.

Since all Mode S replies include the front-face boresight angle, provision must be made in the back-face lookup table to contain entries that are on the order of 180° (2^{13} Au).

30.3.4.12 Sensor start-up.- Sensor start-up for the back-to-back sensor shall be performed as specified in 3.4.12 of the main body of this document except that monopulse calibration must be performed for each antenna face.

30.3.4.13 System timing.- System timing for the back-to-back sensor shall be the same as specified in 3.4.13 of the main body of this document.

30.3.4.14 Test target generator (TTG).- The test target generator for the back-to-back sensor shall function as specified in 3.4.14 of the main body of this document.

30.3.5 Interface design requirements.- In addition to the interface requirements specified in 3.5 of the body of this document, the Mode S sensor designed for a back-to-back antenna configuration shall be required to interface with the en-route Mode S/ATCRBS array and a nine channel rotary joint.

30.3.6 System architecture for reliability.- A redundant front end subsystem containing an interrogator/processor and the reply processors plus performance monitoring and TTG functions shall be used to achieve the reliability requirement specified in 3.9.2 of the body of this document. It shall have the capability of replacing either of the online front-end subsystems, as illustrated in Fig. III-4. The switch configuration shall be such as to enable the spare front end to be connected to the antenna system as either a front or backface replacement or to a dummy load for off-line performance monitoring. When the spare front-end is used in the ATC-BI mode, it shall utilize the front-face antenna for the beacon video.

Performance monitoring of the spare front-end shall be in accordance with 3.4.10 of the body of this document.

30.3.7 Interim Configuration A.- If required by the contract schedule, it shall be possible to install a back-to-back sensor in an interim configuration using an antenna with a single front face antenna. The back face front end will not be installed in this configuration. This interim, sensor shall meet all of the requirements for a back-to-back sensor specified herein except for the absence of data from the back face.

It shall be possible to add the back face front end and a back-to-back antenna system and meet all of the requirements specified herein for a complete back-to-back sensor without making any changes to the interim sensor components other than the modification of software site adaptation parameters.

30.3.8 Interim Configuration B.- If required by the contract schedule, it shall be possible to install a back-to-back sensor in an interim configuration using a back-to-back antenna such that both faces are dedicated to FAA use. The back face front end will not be installed in this configuration. If one of the front ends becomes inoperative, the single operative front end shall allow sensor operation in a single face configuration.

It shall be possible to add the back face front end and meet all of the requirements for the complete back-to-back sensor specified herein without making any changes to the interim sensor components other than the modification of software site adaptation parameters.

This space intentionally unused.

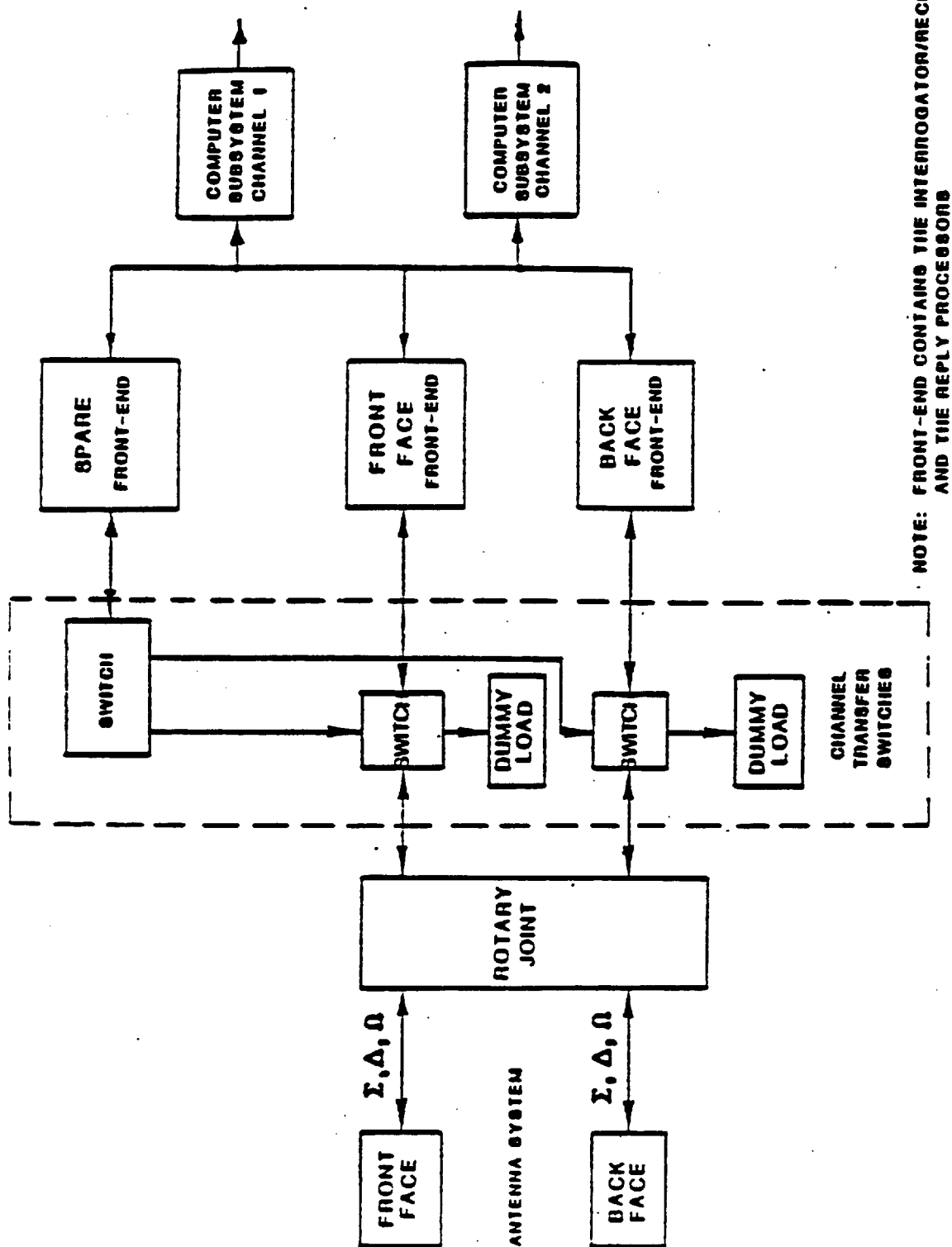


FIG. III-4. MODE S BACK-TO-BACK SENSOR CONFIGURATION FOR SYSTEM RELIABILITY

APPENDIX IV
MODE SELECT BEACON SYSTEM SENSOR
REQUIREMENTS FOR USE WITH
TERMINAL RADAR SYSTEMS

APPENDIX IV
MODE SELECT BEACON SYSTEM SENSOR
REQUIREMENTS FOR USE WITH
TERMINAL RADAR SYSTEMS

40.1. SCOPE AND PURPOSE

40.1.1 Scope.- This appendix specifies the Mode S requirements necessary to render the sensor capable of operating with various terminal radar (ASR) systems. The design is specified in terms of changes and additions to the basic sensor specified in the body of this document.

40.1.2 Purpose.- The purpose of the requirements stated herein is to provide for the data handling and interfacing of radar information from the Radar Digital Acquisition Subsystem (RDAS) portion of the Sensor Receiver and Processor (SRAP) and from the Moving Target Detection (MTD) subsystems.

40.1.3 Implementation.- The software shall be implemented totally separate from the Mode S sensor software, even when sharing of common routines is possible. This requirement is to permit later changes to algorithms if superior radar trackers are developed without affecting Mode S functions. Sharing of a common track file is also prohibited. A parameter switch shall be included which can suppress the radar-only correlation and tracking functions specified in this Appendix.

40.2. DEFINITIONS

40.2.1 Moving Target Detection (MTD).- MTD data shall be transferred to the Mode S sensor from the MTD radar after MTD filtering, thresholding, constant false alarm receiver (CFAR), and other MTD front end processing, plus MTD correlation and interpolation (C&I) processing.

40.2.2 Sensor receiver and processor (SRAP).- The formats and data from SRAP equipment are defined in 3.5.2.5. For RDAS data the following shall be used:

Doppler 1 and 2: 0
Interpolated doppler 1 and 2: 0
Quality: (To be determined)
Confidence: High

40.2.3 Data rate.- Interface design requirements contained in this specification are based upon data rates which do not exceed:

- (a) 1 radar report/aircraft/scan for a maximum of 700 aircraft
- (b) 100 miscellaneous false alarms/scan (nominal)
- (c) a maximum of 300 ground targets
- (d) maximum of 10,000 words (16 bits)/second including weather
- (e) maximum of 150 weather reports/second

40.2.4 Data delays.- Data made available to the Mode S sensor shall arrive at the sensor within 3/64 of a scan after target centroid. Data not available within 3/64 of a scan shall be discarded.

40.3. REQUIREMENTS

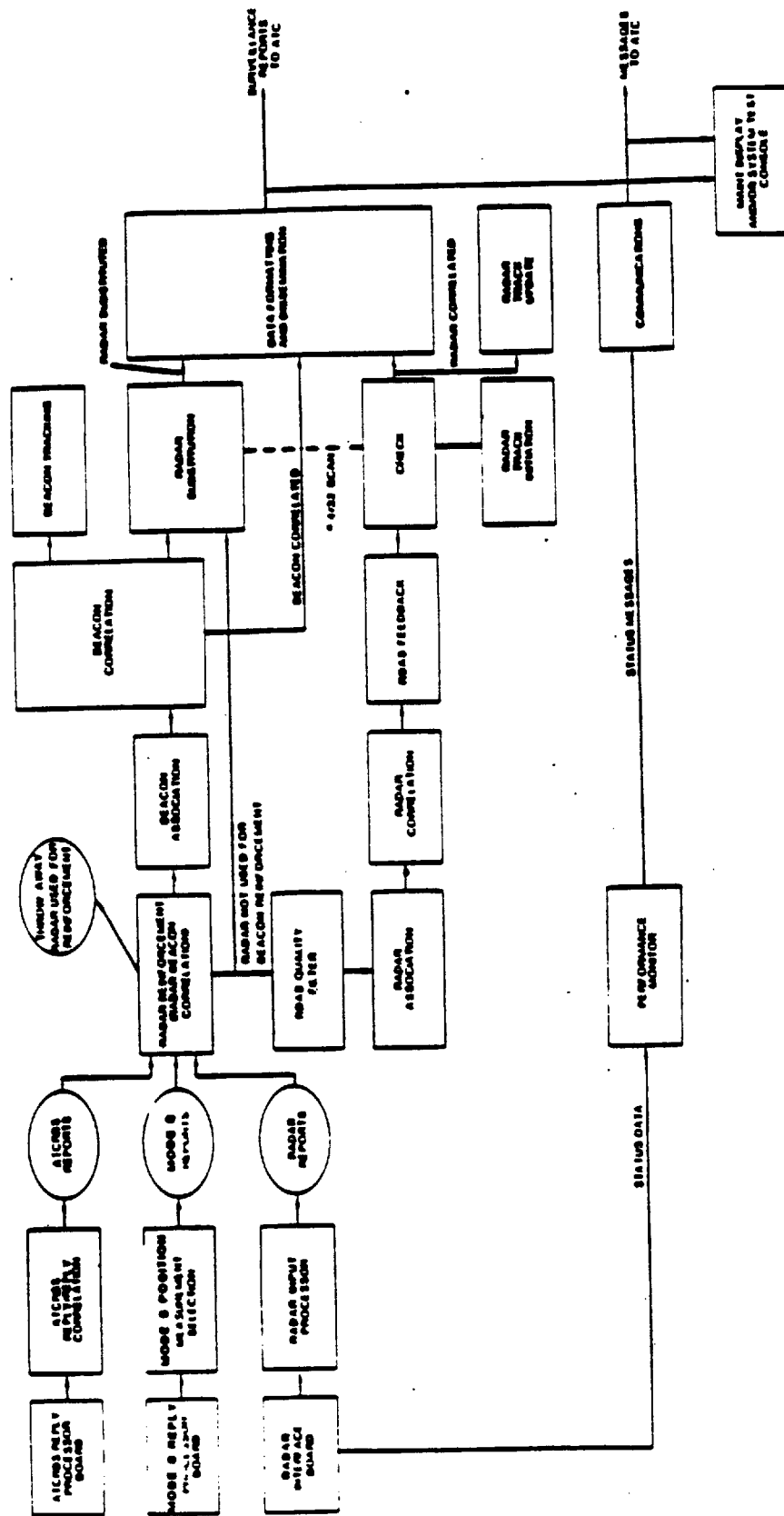
40.3.1 Design requirements.- Unless otherwise specified in this appendix, the hardware and software required herein shall meet all of the requirements specified in the body of this document.

40.3.2 Performance requirements.- A block diagram of the Mode S/Primary Radar operation is shown in Fig. IV-1. This functional diagram is not binding upon the physical arrangement of the software and hardware.

40.3.2.1 Capacity.- The capacity requirements of the main body of this document (3.3.2.5) shall be understood to include radar-only targets in any mix, subject to the data rate limitations of 40.2.3 above, whenever this Appendix is invoked by the contract schedule.

40.3.2.2 Overall operation.- Radar data shall be transferred to the Mode S # sensor from the radar after filtering, thresholding, CFAR, and other front end processing have been accomplished (including correlation and interpolation (C&I) processing when data is from the MTD). The data transfer shall occur via the hardware interface described in 3.5. Data transferred from the radar shall include the following:

- (a) MTD - Radar report data: Target range
Target azimuth
Maximum amplitude, Filter Number PRF-1.
Maximum amplitude, Filter Number PRF-2
Interpolated Velocity PRF-1



Interpolated Velocity PRF-2
Amplitude
Report quality
Confidence
Selected ASR-9 channel status
Radar real-time quality control (RTQC)
targets

- (b) SRAP data: Weather (3.5.2.5)
 Radar reports (3.5.2.5)
 SRAP alarms (3.5.2.5)

Fig. IV-1 illustrates the functional operation of Mode S using radar data. Radar Input Processor software shall transfer radar data from the radar interface to a radar buffer in Mode S. This function also shall add a time tag to each radar report based on: (1) the current time and azimuth, as available from the antenna azimuth and range timing unit (AARTU), and (2) the azimuth associated with the report.

The non-ground target radar report data shall then be used by Mode S Radar/Beacon Correlation to check for radar reinforcement of ATCRBS and Mode S beacon reports. All radar reports which reinforce beacon reports shall be discarded and the corresponding beacon reports designated as "radar reinforced". The remaining radar reports shall be designated as:

- (a) Radar reports associated with a beacon tracked aircraft which received no beacon report this scan. After beacon association/correlation are complete, these reports will be used to form "radar substituted" reports for dissemination,
- (b) Radar reports for aircraft which are currently in the radar-only tracking mode and thus have "radar tracks" in the surveillance file. These reports will be used to update the radar track data and also be disseminated to ATC facilities,
- (c) Radar reports which do not correspond (associate and correlate) with aircraft presently under beacon or radar-only tracking. These radar reports represent false alarms or reports on aircraft that are candidates for radar-only track initiation.

Ground target radar reports shall not be processed by any algorithm in this Appendix. They shall simply be passed unchanged to the dissemination function.

The evaluation of radar data for radar substitution shall not be accomplished until it is determined that a beacon tracked aircraft did not receive a beacon report, i.e., following beacon association and correlation. Likewise radar reports shall not be used to update established radar-only tracks or to initiate new radar-only tracks until radar association and correlation is complete, i.e., it is determined whether the report is for an established track. When beacon correlation is complete (but no later than 3/32 of a scan following target report acquisition), the radar reports shall be checked

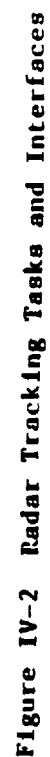
against the results of beacon correlation, i.e., beacon tracks which did not receive beacon reports shall be compared with radar reports. If radar reports correlate to these beacon tracks, the radar report shall be used to form a "radar substituted" report and disseminated as per normal Mode S operation. Radar association and radar correlation software functions shall be used to match radar reports with corresponding radar-only tracks that have previously been established in the Mode S sensor (data in surveillance file). Radar reports which meet the association/correlation criteria shall be used to update the radar-only track data. The track update function shall be similar to that same function used to update Mode S track data using Mode S beacon reports. Radar tracking shall be performed only on front face data, and update shall be for a complete scan. Likewise, no more than one report shall be used to update any one established track per scan. Each selected report shall in turn be passed to the data formatting and dissemination function which shall format the radar report for transmission to the air traffic control (ATC) facilities.

Radar reports that do not correlate with radar-only tracks, or are not used to form "radar-substituted" reports for beacon tracks, shall be made available to the track initiation software function. This function shall monitor uncorrelated reports from scan to scan to determine when sufficient correlation exists to establish a new track, i.e., shall enter track data into the surveillance file and start to disseminate correlated radar-only reports. Track initiation shall start an initial track after reports from two consecutive scans meet range and azimuth comparison criteria and the first report has high confidence. If M reports are not correlated within N consecutive scans, the internal track shall be dropped.

Throughout radar operation, the radar interface shall provide status data indicating the operational condition of the interface. Performance monitor software shall monitor the radar status registers and incorporate information regarding radar status in Mode S sensor status messages which are sent on each scan to ATC facilities. The status messages can also be monitored via the maintenance display and system test console. In addition, both displays shall display radar-only via the respective PPI display.

40.3.3 Software requirements.- The Mode S/Primary radar software system is shown in Fig. IV-2. Three threads are shown in the figure as horizontal flow. The first two threads are for the ATCRBS and Mode S beacon reports. These threads show the flow of the beacon reports through the radar functions. The third thread in the figure shows the flow of radar reports from the Mode S input buffer to the output communication buffer.

The function and data files in the radar thread are listed in the following paragraph, and the required design for each of the radar functions is described in detail in the following subparagraphs.



The system software functions are:

- (a) Primary Radar Input Processor
- (b) Radar/Beacon Correlation
- (c) Data Formatting and Dissemination
- (d) Radar Association
- (e) Radar Correlation
- (f) Radar Track Initiation
- (g) Radar Track Update
- (h) Surveillance Transmit
- (i) RDAS Quality Filter
- (j) RDAS Feedback

Mode S/primary radar data files (not including current Mode S system files) used in radar processing shall be:

- (a) Primary Radar Input Buffer
- (b) Radar Reports
- (c) Weather Messages
- (d) Radar Association Buffer
- (e) Radar Uncorrelated Reports
- (f) Radar Track Initiation File
- (g) Radar Track Update File
- (h) Radar Surveillance File
- (i) RDAS Output Interface Board

Figure IV-3 defines the radar surveillance file:

40.3.3.1 Radar input processor.— The radar input processor function shall provide the input interface between the radar digitizer and the Mode S sensor. This function is tasked with moving the MTD (or RDAS) messages from the radar interface to the appropriate interface buffers.

40.3.3.1.1 Functional requirements.— The radar input processor is tasked with moving radar reports (see Fig. IV-3) and weather reports from the radar interface to the appropriate interface buffers. It shall also separate ground and non-ground targets via reference to the confidence field (00=ground target).

Each radar report shall be time tagged with a calculated time of measurement. The calculated time of measurement shall be derived using the current time of day and azimuth, and the azimuth rate of the sensor, using the following equation:

$$\text{Time of Measurement} = \text{Current Time} - \frac{\theta_{\text{curr}} - \theta_{\text{report}}}{\text{Azimuth Rate}}$$

<u>Field</u>	<u>Field</u>
Time of day	Earliest likely azimuth
Initial range	Initial azimuth
Range rate	Azimuth rate
Predicted range	Predicted azimuth
Doppler 1	Strength
Interpolated Doppler 1	Quality
Doppler 2	Confidence
Interpolated Doppler 2	Track firmness
Track scan count	History firmness
Track miss count	Initial track flag
Maturity count	Track maturity flag
Maximum amplitude, Filter PRF-1	False track flag
Maximum amplitude, Filter PRF-2	

Fig. IV-3. Radar Surveillance File Fields.

Where θ_{curr} = current azimuth of antenna
 θ_{report} = azimuth of the radar report

The radar range and azimuth shall be corrected by adding the collimation correction range (CCR) and collimation correction angle (CCA). The corrected azimuth of each radar report is then used to enter the ATCRBS/radar range mask table. The resulting table value is the maximum permitted sensor range at the azimuth. Radar reports whose range exceeds the sensor maximum range shall be discarded. The age of each radar report shall also be checked and all radar reports that are more than 3/64 of a scan old shall be discarded.

The radar input buffer shall also contain weather reports from the SRAP/RDAS radar digitizers. The radar input processor is tasked with formatting a standard CD surveillance map message and message sequencing using the data provided in the radar input message. The resultant message shall be stored in the radar surveillance transmit output file along with a time tag (the current value of TYEAR3 in the AARTU with the LSB = 1/16 second). The Surveillance Transmit function shall be tasked with transmitting the resultant message to ATC users.

40.3.3.2 Radar association.- The Radar (Target to Track) Association function shall be analogous to the association portion of the ATCRBS target-to-track correlation function of the Mode S sensor (3.4.6.4 of the body of this document). Radar association shall receive radar reports and attempt to associate the radar reports with radar tracks in the surveillance file. The results of the association shall then be passed to radar correlation for correlation processing. This function shall be under the control of the parameter switch specified in 40.1.3.

40.3.3.2.1 Functional requirements.- The radar association function shall receive radar reports from the function radar input processor. These radar reports shall have been range and azimuth corrected by radar input processor and be ready for processing by radar association. However, only radar reports which do not correspond to beacon reports shall be processed by radar association. Thus, radar association shall be required to wait until radar beacon correlation has performed its radar/beacon reinforcement function. Radar/beacon correlation shall begin performing reinforcement when the radar reports have aged for 2 sectors. Radar association shall begin processing the radar reports following completion of reinforcement processing. Radar/beacon correlation shall set a "used" bit in each radar report used to reinforce a beacon report, and these "used" reports shall not be used by radar association.

In performing radar report to radar track association, radar association shall perform the identical tasks as the basic Mode S system task, ATCRBS target to track association, with the following exceptions:

- (a) No Zone 3 processing shall be performed.
- (b) All identity code checks shall be performed using Doppler 1 and Doppler 2 data.

The comparison shall be made according to one of the following options, selectable via site adaptation.

- (1) If either Interpolated Doppler 1 or Interpolated Doppler 2 in the report matches the corresponding track Interpolated Doppler 1 or Interpolated Doppler 2 data respectively, then the identity code shall be considered as agreeing (note: a Doppler code of '0' cannot be matched).
- (2) The test shall be made as in (a) except that a Doppler difference in either Interpolated Doppler 1 or Interpolated Doppler 2 of no more than 2(1-6,1) shall be permitted for identity code agreement in Zone 1 (again, a Doppler code of '0' cannot be matched). The Zone 2 test shall be as in (1).
- (3) All Zone 1 associations shall automatically be rated as identity code agreement, regardless of Doppler disagreement, even for a Doppler code of '0'. The Zone 2 test shall be as in (1).

All three cases apply to radar input. However, since RDAS radar data contains no Doppler values, identity code agreement can occur only if option (3) is selected. Lack of agreement shall be rated as identity code disagreement.

- (c) All altitude checks shall produce agreements.
- (d) No code swapping shall be performed.

The association rules for radar association are summarized by the following rules:

- (a) pairs with code agreement shall be associated.
- (b) pairs with code disagreement of magnitude less than a site adaptable parameter are associated. When the magnitude of code disagreement is greater than or equal to the site adaptable parameter the pair shall be associated tentatively. Since no code swapping shall be performed, resolution of the tentative associations shall be resolved by performing the velocity reasonableness test (3.4.6.4.6.6 of the body of this document). Thus, all pairs with code disagreement which

pass the velocity reasonableness test shall be associated.

As in the basic Mode S system, results of the association logic shall be stored in an association buffer for use by the radar correlation task. As shown in Figure IV-2 (radar tracking tasks and interfaces), a separate radar association buffer shall be used for radar processing. Data stored in the association buffer are pointers to the radar reports which are associated with each radar track. In addition, a quality score calculation is performed for each association pair, and the result of the quality score calculation is stored with each association pair. To permit possible combination of the radar report and beacon report processing, a special quality score definition has been defined for radar associations, such that the quality score result for all radar associations is larger (lower association) than all beacon report associations. The radar report quality score calculation is summarized as follows:

<u>Octal Digit and Factor</u>	<u>Condition</u>	<u>Score</u>
7 - dummy	none	4
6 - dummy	none	7
5 - code and zone	code agree & zone = 1	0
	code agree & zone = 2	1
	code disagree & zone 1	2
	code disagree & zone 2	3
4 - radar validity	TBD	0
3 - track validity	mature & range gt. rmin	0
	mature & range le. rmin	1
	not mature & range gt. rmin	2
	not mature & range le. rmin	3
2,1,0 - deviation score		-

quality score = (D7,D6,D5,D4,D3,D2,D1,D0) octal
where D = Digit number

40.3.3.2.2 RDAS quality filter.- Prior to association processing described above, RDAS target reports shall be subjected to a special quality filter to facilitate blanking of point clutter due to strong ground returns. Only those RDAS reports not associated with beacon reports shall be input to the quality filter.

Operation of the filter is based on a partitioning of the surveillance area into 32 sectors, each containing 344 cells, where cell size varies with range as follows:

0 to 8 nmi:	128 ACPs by 1 nmi
8 to 16 nmi:	64 ACPs by 1 nmi
16 to 32 nmi:	32 ACPs by 1 nmi
32 to 64 nmi:	16 ACPs by 1 nmi

For each cell, a quality threshold (QT) shall be established and maintained by interaction between the two phases of filter processing, referred to as report processing and sector processing. During report processing, the quality field (Q) of each RDAS target report shall be compared against the appropriate cell threshold and the report output to the radar association function if one of the following conditions is satisfied:

1. The quality filter is disabled, or
2. $Q > QT$ or $QT < 2$.

In addition, report processing shall declare a "hit" for the appropriate cell whenever the report quality satisfies the following relationship:

$$Q > QT - 1.$$

To relieve storage requirements for cell data, report processing shall utilize an intermediate work table defining space for each of the 344 cells for the current sector. Following processing of the target reports for a sector, sector processing shall interpret the work table and update the quality threshold for each cell as required. Threshold update shall be accomplished once every SC (system parameter with nominal value 2 (2-8,1)) scans and shall consist of incrementing or decrementing an existing cell threshold according to the following table:

SC	Hit	No Hit
2	+1/4	-1/2
3	+1/4	-1/2
4	+1/2	-1/2
5	+1/2	-1/2
6	+3/4	-1/2
7	+3/4	-1/2
8	+ 1	-1/2

After threshold update, all active cells in the work table (those with $QT > 0$ or a current hit declaration) shall be transferred to a permanent scan file, sized to allow storage of a maximum of 1500 cells. In preparation for report processing of target reports in the next sector, the work table shall be reinitialized with cell data retrieved from the scan file for those active cells in the next sector. Inactive cells shall be initialized with QT and hit indicator set to zero.

Clutter file maintenance shall be performed at all times when RDAS processing is operational; enablement of report screening shall be controllable via site adaptation.

In the event of loss of sector messages from RDAS, filter operation shall be deactivated for one scan, i.e., until the received sector count is one greater than the last sequential count received prior to message loss. During the resynchronization period, output of radar-only reports to radar association shall be inhibited.

40.3.3.3 Radar correlation.- The radar (target to track) correlation function is analogous to the correlation portion of the ATCRBS target-to-track correlation function of the Mode S sensor (3.4.6.4 of the body of this document). Radar correlation shall receive radar report to radar track associations and then perform the radar report to radar track correlation. Results of the correlation shall be passed to radar track initiation and radar track update for additional processing. This function shall be under the control of the parameter switch specified in 40.1.3.

40.3.3.3.1 Functional requirements.- The radar (target to track) correlation function shall receive radar associations from the radar association buffer. Each track in the association buffer shall be sized for three possible radar report associations and the following information shall be stored with each association:

- (a) Pointer to the associated radar report.
- (b) Association quality score.
- (c) Link word to other radar tracks in the association buffer which are also associated with the radar report.

Using the correlation algorithms defined in 3.4.6.4 of the body of this document, radar correlation shall perform the radar report to radar track correlation function. Results of the correlation processing shall be stored for the correlated report (the surveillance file index of the correlated track) and in the surveillance file entry of the correlated track (the index of the correlated report). These correlation pointers shall be used by radar track update to update the surveillance file entry for the radar track. In addition, pointers to all uncorrelated radar reports shall be stored for use by radar track initiation in initializing new radar tracks.

40.3.3.4 Radar/Beacon correlation.- The Radar/Beacon Correlation (RBC) function shall be tasked with reinforcing Mode S and ATCRBS beacon reports, performing radar substitutions on coasting Mode S and ATCRBS tracks, and with declaring residual radar reports as radar-only reports.

40.3.3.4.1 Functional requirements.- The Radar/Beacon Correlation (RBC) function for the MTD/RDAS system shall be functionally equivalent to the basic Radar/Beacon correlation as defined for the CD in the body of this document.

The only differences shall be the processing associated with radar-only reports, the source of the input data, and the revised substitution role presented in 3.3.4.1.1.

RBC shall perform its radar reinforcement function of beacon reports when the beacon reports are 2 sectors (system parameter) old. This allows for the delays involved in declaring the radar report in the MTD or RDAS and getting the radar report into Mode S. Radar reports that are used to reinforce a beacon shall have their "used" flag set in the report as a flag to radar tracking indicating that this radar report cannot be used to update a radar track. Radar substitution shall be performed by RBC when the tracks are 5 sectors (system parameter) old. This allows for ATCRBS target to track correlation to correlate close-in tracks. When the radar reports are 5 sectors (system parameter) old, RBC shall scan the radar report file and move all radar reports that associate 1-on-1 with a coasting beacon track to the radar substitution file. Radar reports that are used in a radar substitution shall have their "used" flag set in the report as a flag to radar tracking indicating that this radar report cannot be used to initiate or to update a radar track.

40.3.3.4.1.1 Termination of radar substitution.- When a beacon track that is undergoing radar substitution has not received a correlating beacon report for $S = K(K-10, 1)$ scans (where K is specified in 3.4.6.10.4.1 of the main body of this document), the track shall be converted to a radar-only track at the time of the next correlating radar report. It shall then be subsequently updated according to the rules of this Appendix. (See 3.3.7.1.(m) of this Appendix). This track shall be passed to the radar track update function via an interface buffer. After the track has been dropped from all ATCRBS or Mode S lists, the track number will be stored into the interface buffer for use by the radar track update function. For Mode S tracks, prior to the Mode S-track-to-radar-track transition, provision shall be made for disseminating to non-correlating users the surveillance file-number-to-discrete-address pairing. For ATCRBS tracks, the transition from ATCRBS tracks, the transition from ATCRBS track to radar track shall maintain surveillance file number continuity as seen by users of the surveillance data.

40.3.3.4.1.2 Cone of silence substitution.- No radar substitution shall be attempted when the beacon track is in the radar antenna cone of silence. This condition is signalled by the Radar Zenith Cone Flag being set to one in the beacon track file.

40.3.3.5 Data formatting and dissemination.- The data formatting and dissemination function shall be tasked with formatting surveillance reports (Mode S, ATCRBS, and radar) and disseminating those reports based on a dissemination map separately defined for each ATC facility (3.4.6.14.3).

40.3.3.5.1 Functional requirements.- The data formatting and dissemination function shall be functionally equivalent to that function as defined in the main body of this document, section 3.4.6.14. The only difference is the processing associated with the formatting and dissemination of radar-only reports.

Dissemination of radar data shall occur for both correlated and uncorrelated target reports. All correlated reports shall be disseminated to all users, and all uncorrelated and ground target reports shall be disseminated to correlating users. Uncorrelated data and ground target reports shall be disseminated to non-correlating users according to one of the following options, selectable via site adaptation:

- (a) No dissemination of uncorrelated data.
- (b) Disseminate all uncorrelated reports for which the quality and confidence values meet separately adjustable site-adaptable thresholds.
- (c) Begin dissemination for a track with the second report of each association pair used by the track initiation function to initialize new tracks, provided the quality and confidence of that report meet separately adjustable site-adaptable thresholds.

Limitation of the regions in which dissemination of uncorrelated radar reports is allowed shall be accomplished via a site-adaptable coverage map defining a minimum of 30 range cells for each of 32 sectors, centered on the sensor location. Qualifying reports shall be disseminated based on an indicator in the appropriate cell.

Reports that correlate with existing tracks shall be disseminated to both correlating and non-correlating users as correlated data only after the corresponding track has been declared mature. Maturity is defined as the occurrence of correlation for K scans, where K is a site-adaptable parameter with nominal value 3(2-15,1). If either option "b" or option "c" above has been selected, reports that correlate prior to scan K shall be disseminated as uncorrelated data. Normal ATC dissemination rules shall apply to the dissemination of correlated radar reports.

When either option "a" or option "b" has been selected, dissemination of correlated data shall occur at a report age not greater than 6 sectors. When option "c" has been selected, both correlated and uncorrelated data shall be disseminated at a report age not greater than 7 sectors.

The radar report shall be formatted for dissemination to ATC users. Included in the report format shall be a false track bit which dissemination shall set when the associated surveillance file radar track is flagged as false.

40.3.3.6 Radar track initiation.- Addition of a Mode S/radar interface requires the additional function of radar track initiation. This function introduces radar tracks into the Mode S system based on uncorrelated radar reports. These reports will be passed to radar track initiation by the radar track association/correlation functions. This function shall be under the control of the parameter switch specified in 40.1.3.

40.3.3.6.1 Functional requirements.- The primary function of radar track initiation is the establishment of tracks generated from uncorrelated radar reports. The methods used to generate radar tracks shall be essentially the same as the basic Mode S track initiation function, as per the main body of this document, 3.4.6.9. Several modifications are necessary to the Mode S track initiation function to make it applicable to the radar track initiation function.

- (a) Mode S false target processing shall be replaced by a test on the radar report confidence bit. If the bit is not set (low confidence), the report shall not be entered into the local last scan file for future track initiation processing; however, low confidence radar reports may be used to form the second half of a report pair for radar track initiation.
- (b) The reasonableness test requires separate system parameters from Mode S or ATCRBS in order to associate the initial radar reports. Holding the initiation box to a size consistent with a 660 knot aircraft should be the default value:

$$\Delta \rho_{\max} = R_p * T_{\text{scan}}, R_u$$

$$\Delta \theta_{\max} = \frac{R_p * T_{\text{scan}}}{\rho} * \frac{2^{13}}{\pi}, A_u$$

$$R_p = 40(30-100,5)$$

$$T_{\text{scan}} = \text{Scan Time}$$

- (c) Since radar data is not "handed off" from sensor to sensor, there will not be any radar tracks initiated via the track data message buffer.
- (d) The uncorrelated radar reports not used to start new tracks shall be placed in a holding file for one scan and used to associate with incoming radar reports on the next scan. Reports appearing for the first time on the new scan are saved for the next scan. Reports in the holding file which do not associate with a new report are purged after one and a half scans. This is the same mode of processing that

is used in both ATCRBS and Mode S track initiation for the basic Mode S sensor. In addition, though, uncorrelated radar reports within 5(1-20,1) miles of the sensor that are successfully used to initiate new tracks shall still be placed in the holding file for use next scan. This provides a report which incorrectly correlated with a clutter or false alarm report a second chance to form the correct track.

- (e) To avoid using a radar report that has been used by radar/beacon correlation for track substitution, radar track initiation must check the "used" bit in the radar report. If the "used" bit is set, the report was used for track substitution and is not available for radar track initiation. Radar track initiation will run 6 sectors behind the antenna. This will permit radar/ beacon correlation to complete track substitution processing.
- (f) A radar track is initiated when a report is received on two successive scans. A flag will be set in the surveillance file to indicate that this is an initial track, as opposed to a normal radar track. To permit the M out of N test, radar track initiation shall initiate a track scan count and a track miss count for the radar track in the surveillance file.
- (g) The track number for an initial track shall be retrieved from the current free space pool of pointers buffer. To prevent the radar from creating so many false alarm tracks that too few are left for beacon targets, a separate radar surveillance file shall be employed. This file shall be sized 50 percent above the maximum sensor aircraft capacity.
- (h) Radar track initiation shall initialize parameters for each radar track for use in radar false track processing. If a radar track is initialized with a range less than 4000 (8000,100) Ru, the radar false track flag shall be set and the range and azimuth of the first half of the report initiation pair shall be stored in the surveillance file for processing by the radar track update and the data formatting and dissemination functions.
- (i) As a site-adaptable option, the radar track initiation function shall perform the additional task of RDAS feedback, which is the routing of RDAS uncorrelated reports to an output buffer for delivery to the RDAS target processor, when the target processor is connected to the sensor. A report shall qualify for output when it has failed to correlate with an existing track or beacon report.

40.3.3.7 Radar track update.- Addition of a Mode S/radar interface requires the additional function of radar track update. This function shall update radar tracks in the Mode S system that were established by the radar track initiation function, or converted by the radar substitution function, and correlated by the radar target to track association/correlation functions. This function shall be under the control of the parameter switch specified in 40.1.3.

40.3.3.7.1 Functional requirements.- The primary function of radar track update shall be the smoothing and prediction of track data on a scan by scan basis. The methods used to update radar tracks shall be essentially the same as the basic ATCRBS track update function, as per the body of this document, 3.4.6.6. Modifications shall be made to the ATCRBS track update function to make it applicable to the radar track processing as follows:

- (a) No linked track processing shall be required in the radar track update function.
- (b) All calculations dealing with Zone 3 association parameters shall not be required. There shall be only two association zones.
- (c) The radar tracks shall be kept in a separate linked list structure using the same list update methods as ATCRBS track update. The tracks shall be azimuth-ordered based on their earliest Zone 2 azimuth.
- (d) Because no radar data is "handed off" from sensor to sensor, the zenith cone processing shall not be required.
- (e) Code-in-transition processing shall not be required, but the Doppler 1 and Doppler 2 values of the correlating report must be placed in the track file.
- (f) Radar track update is responsible for determining when a radar track has transitioned from the "initial" state to the "normal" state. This transition occurs when the radar track passes the "M out of N" criterion. The radar track update function will determine the number of correlated radar reports, "M", from the track scan count and the track miss count. It will compare this to the number of scans, "N", which is the track scan count. When the number of correlated reports received within "N" scans is met, the track has become a normal radar track, and the initial track flag will be reset. Nominal values are $M = 3(2,15,1)$ and $N = 4(3,15,1)$.
- (g) If an initial track does not meet the "M out of N" criterion, radar track update will drop the track from the Mode S system and its surveillance pointer is added to the free space pool of pointers.

- (h) A new system parameter is required by radar track update to determine when to drop a normal radar track. The track is dropped from the Mode S system after "X" consecutive scans, where "X" is the new system parameter, and has a nominal value of 4.
- (i) The radar track update will require a new track update buffer for use by the data collection function.
- (j) False radar track processing shall be performed on all radar tracks which are initiated with their false track flag set. If the false track flag is set, the current report range and azimuth shall be compared with the radar track's initial range and azimuth. If the range difference exceeds 50(25-100,5) Rm or the azimuth difference exceeds 128(32-256,8) Au, the track will no longer be typed as false and the false track flag shall be cleared. However, if the false track flag remains set, the track scan count will be incremented and when the track scan count = 10 (system parameter), the false track will be dropped from the surveillance file.
- (k) The Mode S and ATCRBS tracker shall be modified to an Alpha/Beta filter for azimuth, the values for Alpha and Beta determined based on the radar report quality value (Q) as follows:

Q	Alpha	Beta
0	0.50	0.25 * value in Table 3.4.6-3
1	0.75	0.50 * value in Table 3.4.6-3
2	1.00	0.875 * value in Table 3.4.6-3
3	1.00	0.875 * value in Table 3.4.6-3

To smooth the track's azimuth prior to update, the following equation shall be used:

$$\text{NEW AZIMUTH} = (1 - \alpha) * \text{PREDICTED AZIMUTH} + \alpha * \text{NEW AZIMUTH}$$

To smooth the track's azimuth rate prior to update, the usual equation shall be used, although with the modified value of β :

$$\begin{aligned} \text{NEW AZIMUTH RATE} = & \text{PREDICTED AZIMUTH RATE} \\ & + \beta * (\text{NEW AZIMUTH} - \text{PREDICTED AZIMUTH}) \end{aligned}$$

The smoothing of range and range rate shall be unchanged from the equations and values of β given in 3.4.6.10.4.1. When the target is in region 3, and x,y tracking is employed, smoothing of both x and y shall remain unchanged from 3.4.6.10.4.2.3(b).

- (1) When a radar track is dropped from the surveillance file, the current count of active radar tracks shall be decremented.

- (m) A buffer providing the interface between both ATCRBS and Mode S track update and the radar track update function shall exist for beacon tracks that have exceeded the radar substitution timeout limit. The radar track update function will include the track number into the appropriate track list, just as if it were a track initiation. The interface buffer will be monitored in the same manner as the radar track initiation file. Before entry is made into the radar track lists, the data of the beacon track will be modified to reflect the normal data of radar track. Entry into the radar track lists will be made immediately upon receipt in the interface buffer. This will provide for dissemination for the next scan radar report as correlating to a radar track, with no interruption of disseminated data.

40.3.3.8 Surveillance transmit.- The surveillance transmit function shall handle weather reports that have been placed in the radar surveillance transmit output file by the radar input processor function. Weather reports have no time-in-storage field and shall be handled as a map or status message and discarded if older than the value prescribed for discard of radar reports. Surveillance transmit controls the transfers of this weather data from the Mode S sensor to appropriate ATC facilities as specified by current dissemination rules (site adaptable).

40.3.3.9 Performance monitor.- The performance monitor function of the Mode S sensor shall be modified to allow monitoring of the radar interface. Status information from the radar that are passed to the Mode S sensor via the interface card shall be monitored.

40.3.3.9.1 Functional requirements.- A primary function of the Mode S performance monitor function is the handling of error conditions reported via interface boards. Since the radar interface to the Mode S system will be implemented using a Mode S interface board, the performance monitor function shall be modified to accommodate an additional interface board.

The performance monitor decision tables shall be expanded to include the status information associated with the interface. "Countable" faults and fatal faults shall be reported as per status processing associated with other interfaces of this type.

Additional status codes and messages shall be defined for the status associated with the interface. These status codes shall also be added to the maintenance display (3.3.10). Definition of the status associated with the radar interface shall be approved during design review.

In addition to status codes associated with the interface, the performance monitor function shall transmit a yellow status condition when the current count of active radar tracks has reached the system maximum.

40.3.3.10 Maintenance display.- Inclusion of radar reports in the disseminated surveillance data shall necessitate the maintenance display software to display radar data. The data extraction subsystem shall be capable of recording the radar surveillance data.

40.3.3.10.1 Functional requirements.- Radar reports shall be processed and displayed on the maintenance display in the same manner that CD radar data is handled by these functions for the basic Mode S system. Modifications shall be required in the following areas:

- (a) Decode radar report.
- (b) Display radar report symbols on PPI display using same symbols as for radar-only reports.
- (c) Upgrade status message display to reflect YELLOW/RED status conditions associated with MTD or RDAS status conditions.

40.3.4 Hardware requirements.- In addition to the interface requirements specified in 3.5 of the body of this document, a hardware interface, ref. FAA-E-2704, shall be provided between the sensor and the MTD subsystem.

This space intentionally unused.

FAA-E-2716
APPENDIX V

-V-1-

APPENDIX V

MODE SELECT BEACON SYSTEM SENSOR

MODE SELECT REQUIREMENTS FOR JOINT-USE SITES

APPENDIX V

MODE SELECT BEACON SYSTEM SENSOR

MODE SELECT REQUIREMENTS FOR JOINT-USE SITES

50.1. SCOPE AND PURPOSE.

50.1.1 Scope.- This appendix specifies Mode S requirements necessary to render the sensor capable of operating as a part of a joint-use site. The design is specified in terms of changes or additions to the basic sensor specified in the body of this document including Appendix III (Mode S Sensor Design for Back-to-Back Antenna Configuration).

50.1.2 Purpose.- The purpose of the Mode S joint-use configuration is to permit the FAA and the Air Defense Command (ADCOM) to share a back-to-back beacon antenna and the Mode S Interrogator and Processor.

50.2. DEFINITION

50.2.1 Joint-Use site.- A joint-use site is an enroute surveillance facility established to provide beacon, search radar, and weather data to the FAA and the Air Defense Command (ADCOM). AIMS (Mode 4) reports are required by ADCOM. Although Mode 4 transmissions shall normally be provided from the front face antenna, site adaptation shall permit Mode 4 transmissions from either the front or back face. Height finder reports are also required by ADCOM, however height finder transmissions will be provided by a special height finder radar not related to the Mode S sensor.

50.2.2 Common digitizer (CD).- Although the text refers to the CD as the Joint Surveillance Site (JSS) digitizer, at the ARSR-3 sites the Digital Target Extractor (DTE) and the Military Interface Module (MIM) are the functional equivalents to the CD. JSS operation shall be performed at either the CD or ARSR-3 sites.

50.3. REQUIREMENTS

Note: The following requirements are based on the use of a separate front end subsystem for each antenna face. Other implementations that use digital switching to share some of the front end elements between the antenna faces, and/or use two separate identical channels (as specified in 3.7 of the main body of this specification), may be used.

50.3.1 Design requirements.- Unless otherwise specified in this Appendix, the Mode S hardware and software for joint-use site operation shall meet all of the requirements specified in the body of this document, and in Appendix III (Mode S Sensor Design for Back-to-Back Antenna Configuration).

50.3.2 Performance requirements.- A block diagram of Mode S in use at a joint-use site is shown in Fig. V-1. This functional diagram is not binding upon the physical arrangement of the hardware.

50.3.2.1 Overall operation.- Mode S operation at a joint-use facility shall be the same as at a standard FAA enroute facility until ADCOM determines that a military transmission is required. At such time ADCOM sends a Mode 4 or height request message to the common digitizer (CD). Height finder requests are passed directly to the height finder radar and resulting reports are returned to the CD. Mode 4 requests are passed to the AN/GPA-124. Mode 4 requests require the use of the Mode S front face antenna and front-end, thus a cooperative action must be initiated to cause Mode 4 operation. Figure V-1 illustrates Mode S operation in a joint use environment. The illustration depicts the normal configuration in which the Mode 4 operation is provided by the front-face antenna. Alternatively, back-face antenna operation for Mode 4 may be accomplished by site adaptation and by a physical reconfiguration of the cabling between the AN/GPA-124 and the front-end subsystem.

The AN/GPA-124 raises a Mode 4 enable signal to Mode S channel management. Following completion of any current front-face Mode S transmissions, channel management shall cease further Mode S transmissions and shall cause the front-face Interrogator-Processor to be switched to Mode 4 operation. In the Mode 4 configuration the front-face front-end shall be required to operate as a self contained ATCRBS interrogator independent of channel management in order to provide mode interlaced ATCRBS as well as Mode 4 transmissions during the Mode 4 request period. The Mode 4 configuration shall also provide the necessary interface between the front-face front-end and both the AN/GPA-124 and the common digitizer for transfer of Mode 4 interrogation triggers, a beacon mode trigger pair, and reply video. At the completion of Mode 4 operation channel management shall cause the front-face front-end input to be switched back to the normal Mode S mode of operation.

Logic within the Mode S sensor shall accomplish the following when Mode 4 is enabled ("Mode 4 enable" signal is "high"). The Mode S sensor shall:

- (a) Recognize that the "Mode 4 enable" signal is high and cease Mode S transmission on the forward-looking antenna.

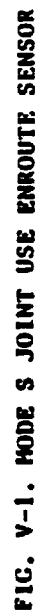


FIG. 5-1. MODE S JOINT USE ENROUTE SENSOR

- (b) Switch the front-face front-end to Mode 4 operation.
- (c) Set current azimuth (azimuth start) in next entry of azimuth pair buffer.
- (d) Set the front face disable flag for channel management.

When the Mode 4 transmission is complete the AN/GPA-124 shall lower the "Mode 4 enable" signal, and Mode S sensor logic shall accomplish the following:

- (a) Recognize that the "Mode 4 enable" signal is low.
- (b) Switch the front-face front-end to the Mode S mode.
- (c) Set the current azimuth (azimuth stop) in the next entry of the azimuth pair buffer.
- (d) Reset the front face disable flag for channel management.

When the Mode S channel management software recognizes that the front face disable flag is set, it shall cease scheduling transmissions for the front face antenna and not resume transmissions to this face until the front face disable flag is reset. Normal scheduling of transmissions for the back face shall continue as required during Mode 4 operation. This procedure shall assure maximum update of Mode S sensor beacon tracks in an environment where Mode 4 operation is required, i.e., monopulse beacon reports are lost from the front face only during azimuth sectors in which Mode 4 transmissions are explicitly required.

During Mode 4 operation the front-face front-end shall be switched by channel management to an independent mode of operation. In this mode the front-end shall have the capability of generating, independent of channel management, Mode 2, 3A, and C transmissions relative to and at the PRF of a radar pretrigger. A pretrigger delay adjustment of 3 - 150 μ sec shall be provided for positioning the P3 pulse relative to the radar pretrigger. Additionally the front-end shall accept Mode 4 modulation signals from the AN/GPA-124 for generation of Mode 4 transmissions. These signals are timed to interlace with the internally generated Mode 2 and ATCRBS transmissions.

The front-end shall provide quantized beacon reply video to the AN/GPA-124 for Mode 4 processing and to the CD-2 for Mode 2 and ATCRBS processing. The ATCRBS replies are processed by the CD-2 to provide ADCOM with front-face beacon surveillance data during the Mode 4 request period. The CD-2 surveillance data is sent directly to ADCOM. The front-end shall also provide a P1-P3 beacon mode trigger pair to the CD-2 for ranging, mode identification and ATCRBS/Mode 4 synchronization.

Mode S data formatting and dissemination software shall be modified to monitor the azimuth pair buffer and to prepare ADCOM formatted beacon and radar reports. These reports are sent to the CD-2 via the standard Mode S/CD-2 surveillance link for dissemination to ADCOM. Each beacon and radar report disseminated to ADCOM with azimuths between the azimuth start/stop pair will be flagged (Mode 4 present bit set). The location of this "Mode 4 present" bit is defined in 50.3.3.3.1.

In summary, ADCOM notifies the Mode S sensor (via the CD) that the front face of the enroute antenna is required for Mode 4 and ATCRBS transmissions from azimuth A to azimuth B. Mode S switches the front-face front-end to Mode 4 operation and disables scheduling of Mode S/ATCRBS transmission to the front face during the Mode 4 period.

Mode S flags all beacon and radar reports received from Mode 4 azimuth sectors with Mode 4 present and transfers them to the CD-2 for dissemination to ADCOM.

50.3.3 Sensor design requirements. - The following subparagraphs describe the details of the modifications required to support joint-use site operation of Mode S.

50.3.3.1 Modulation control unit. - The modulation control unit (MCU) ordinarily receives the input information specified in 3.4.2.1 of the body of this document for each transmission. In the event of a request for Mode 4 operation, the MCU shall accept Mode 4 modulation signals from the AN/GPA-124, as specified in 50.3.4.1(b), for generation of Mode 4 transmissions. The MCU shall also generate ATCRBS interrogations via the front face, independent of channel management, at a time relative to a radar pretrigger as specified in 50.3.3.1.1.

50.3.3.1.1 Auto interlace operation. - The MCU shall have the capability of generating transmissions without channel management control. Three separate mode intervals, designated X, Y, and Z, represent time intervals between radar pretriggers during which any of the 3 modes (2, 3/A, C) may be transmitted. The MCU shall have separate mode selection switches for each designator interval to permit different mode interrogation during each interval. In addition, the MCU shall have an interlace selection control to permit selecting various patterns of interlacing the designator intervals. Seven patterns that can be selected shall be: continuous X, continuous Y, continuous Z, XYXY ..., XXXXY ..., XYZYZ ..., XXXZZXZ ... patterns.

50.3.3.2 Channel management. - Channel management is that portion of the Mode S system (3.4.1 of the main body of this document) which controls all activity on the Mode S RF channel. In the basic back-to-back Mode S system (Appendix III), RF commands are scheduled by channel management to one or both antenna faces to perform the required aircraft interrogation and communication

activity. In the joint-use site, channel management is required to monitor the requested use of the front face antenna for Mode 4 operation and to inhibit front face interrogation and switch the front-end to mode 4 when Mode 4 operation is requested.

50.3.3.2.1 Functional requirements. - In the joint-use site, channel management beacon scheduling shall be required to monitor the Mode 4 enable flag and to switch the front-end and refrain from requesting RF activity on the front face antenna when the Mode 4 enable flag is set. Since channel management may have outstanding requests for front face antenna activity previously linked on the modulation control unit interface channel, some commands for front face antenna activity may reach the modulation control unit. All requests for front face antenna activity which are not honored by the transmitter are to be processed by the modulation control unit and the Mode S reply processor. The result of these commands shall be a "no reply" detection.

Channel management shall be permitted to complete any scheduling activity it is in the process of performing when the Mode 4 enable flag is set, and then check the status of the enable flag when a suitable place is reached in the scheduler main sequence logic. Since channel management is allowed to complete any scheduling activity in progress, the Mode S sensor shall be allowed a 25 msec period between the time that the Mode 4 request is received and processed.

Modifications to the main scheduling function shall include checking the Mode 4 enable flag before performing any front face antenna activity. Thus, a check of the enable flag is inserted before calling any front face scheduling or allocation routine, and a flag is set in the scheduler to inhibit the front face antenna processing. It should be noted that allocation must be informed of the deletion of scheduling on the front face antenna so that all available channel time can be allocated to the back face antenna.

50.3.3.3 Data formatting and dissemination. - The data formatting and dissemination function shall format surveillance reports (Mode S, ATCRBS, and either CD or MTD radar) per 3.4.6.14.2.1 of the body of this specification, and disseminate these reports to the FAA based on a coverage map defined for the site.

The data formatting and dissemination function shall also prepare modified beacon and radar surveillance reports for ADCOM and disseminate these reports to the CD-2. Table V-4 defines the format of the Mode S Request Message from ADCOM to the CD-2. It is included here for reference purposes only.

This space intentionally unused.

50.3.3.3.1 Functional requirements. - The data formatting and dissemination function is equivalent to the current function as defined in the body of this document, Section 3.4.6.14. The modifications for joint-use sites require that additional functions be added to the existing task: setting the Mode 4 present flag in beacon and radar reports disseminated to ADCOM.

The data formatting and dissemination function shall disseminate surveillance data to the ADCOM via the CD-2 using the ADCOM surveillance formats specified in FAA-RD-80-14.

This space intentionally unused.

-V-9-

FAA-E-2716
APPENDIX V
SCN-15 (Change 21)

This page intentionally unused.

This page intentionally unused.

-V-11-

FAA-E-2716
APPENDIX V
SCN-15 (Change 21)

This page intentionally unused.

This page intentionally unused.

-V-13-

FAA-E-2716
APPENDIX V
SCN-15 (Change 21)

This page intentionally unused.

TABLE V-4

MODE 4 REQUEST MESSAGE FORMATS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	A ₃	ID	RS	0	0	0	0	0	0	T	NR1	NR2	NR3	NR4	P	0	0	0
2	1	A ₂	0	0	0	0	0	0	0	0	0	0	0	0	0	P	0	0	
3	1	A ₁	0	0	0	0	0	0	0	0	0	0	0	0	0	P	0	0	
4	A ₅	0	0	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	0	0	0	0	P	0	0	
5	A ₆	0	0	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	0	0	0	0	P	0	0	

<u>Symbol</u>	<u>Meaning</u>	<u>Symbol</u>	<u>Meaning</u>
A	Site Address	PI	Priority Indicator (-0)
HF	Height Finder Designator (-0)	LS	Long-Short Indicator (-0)
ID	Message Identifier (0=HEIGHT FINDER; 1=AIMS)	S	Task Assignment
H	Old Height	R	Request Number
X	X Coordinate	NR	Number of Revolutions
Y	Y Coordinate	ST	Start Azimuth
±	Sign Bit (See Note 3)	SP	Stop Azimuth
P	Parity (Even)	RS	Radar Scan
		T	Loop Test

- Notes: (1) The 91 bits in the message will be received in columnar order, beginning with column 1, row 1 through row 5; column 2, row 1 through row 5, and so on through column 19.
- (2) The postscripts of "1" denote the least significant bits of the indicated words.
- (3) The following conventions apply to the X and Y sign coordinate values:

(a) <u>Sign Bit</u>	<u>Sign</u>	(c) <u>Sign Convention</u>	<u>Antenna Azimuth</u>
0	Positive	+Y, X=0	0°
1	Negative	+X, Y=0	90°
(b) Negative values are transmitted in ones complement form.		-Y, X=0	180°
		-X, Y=0	270°

Data formatting and dissemination shall set the Mode 4 present flag for all beacon reports disseminated to the ROCC whose azimuths lie between a start and stop azimuth when Mode 4 was enabled. This shall require the buffering of start and stop azimuths for one-half of a scan when the Mode 4 interrogations are transmitted from the back face of the antenna (nominally 180 degrees out of phase with the front face azimuth). To accomplish this, data formatting and dissemination shall monitor the Mode 4 enable, start azimuth, and stop azimuth data, and sense when Mode 4 has been enabled and disabled. As beacon reports are disseminated, data formatting and dissemination shall check to determine if the azimuth of the report falls within an azimuth wedge defined by the saved start/stop azimuth windows. All reports disseminated to the ROCC during these azimuth windows shall have the mode 4 present flag set to 1.

50.3.4 Interface design requirements. - In addition to the interface requirements specified in Paragraph 3.5 of the body of this document and in Appendix III, hardware interfaces shall also be provided between the sensor and the following two systems.

- (a) AN/GPA-124 (per T.O. 31P4-2GPA124-2)
- (b) Common Digitizer (CD-2, per FAA-E-2679)

The principle characteristics of these interfaces shall be as specified in 50.3.4.1 and 50.3.4.2. For overall operation see 50.3.2.1.

50.3.4.1 AN/GPA-124. - Hardware interfaces shall be provided between the AN/GPA-124 and the following elements of the Mode S sensor.

- (a) Channel Management: When a Mode 4 interrogation is to be made, the AN/GPA-124 will raise the "Mode 4 enable" signal to a "high" level. This signal shall be sent to channel management. Its characteristics are as follows:
 - Low Level - -0.5 to +0.5 volts
 - High Level - +3 to +5 volts
 - Impedance - 85 to 96 ohms
- (b) Front-Face Interrogator: When the "Mode 4 enable" signal goes "high" channel management shall cause the front-face Interrogator to switch from Mode S transmission control to an independent mode of operation. In this mode the Interrogator shall be capable of accepting the following three Mode 4 modulation signals from the AN/GPA-124 and generating an interlaced pattern of Mode 4, Mode 2, and ATCRBS transmissions.

These signals are provided on separate 75-ohm cables:

Decoy Interrogation Pulses

Amplitude 20 \pm 4 volts
Pulse Width 0.8 μ sec

SLS Interrogation Pulse

Amplitude 20 \pm 4 volts
Pulse Width 0.3-1.5 μ sec

Mode 4 Interrogation ("Challenge") Pulses

Amplitude 20 \pm 4 volts
Pulse Width 0.5 μ sec

- c. Front-face Processor - The front-face processor shall provide a quantized sum video signal to the AN/GPA-124 with the following characteristics:

<u>Quantized Video</u>	<u>Nom. Value</u>	<u>Extremes</u>
Amplitude (Adjustable)	+2.0 volts	+1.0 to +5.0 volts
Baseline	0.0 volts	-1.0 to +1.0 volts
Pulse Duration	0.45 μ sec	0.1 to 2.0 μ sec*
Rise Time	0.1 μ sec	maximum
Fall Time	0.1 μ sec	maximum
Noise Level	+0.1 volts	+2.0 volts max.
Impedance	75 ohms	70 to 80 ohms

*Width of a non-overlapping pulse \leq 0.60 μ sec;
2.0 μ sec reflects an overlapping condition.

50.3.4.2 Common digitizer (CD-2) - Hardware interfaces shall be provided between the CD-2 and the following elements of the Mode S sensor.

- Computer Subsystem - An additional interface shall be provided between the Mode S computer subsystem and the CD-2 for dissemination of ADCOM surveillance reports. This surveillance link shall be a standard IEEE-488 8-bit parallel data bus.
- Front-Face Processor - The front-face processor shall provide a quantized sum video signal to the CD-2 with the following characteristics:

<u>Quantized Video</u>	<u>Nom. Value</u>	<u>Extremes</u>
Amplitude (Adjustable)	+2.0 volts	+1.0 to +5.0 volts
Baseline	0.0 volts	-1.0 to +1.0 volts
Pulse Duration	0.45 μ sec	0.1 to 2.0 μ sec*
Rise Time	0.1 μ sec	maximum
Fall Time	0.1 μ sec	maximum
Noise Level	+0.1 volts	+2.0 volts max.
Impedence	75 ohms	70 to 80 ohms

*Width of a non-overlapping pulse \leq 0.60 μ sec;
2.0 μ sec reflects an overlapping condition.

- c. Front-Face Interrogator - In the ATC BI mode the front-face interrogator shall provide a P1-P3 beacon mode trigger pair to the CD-2 with the following characteristics:

Amplitude	+10 to +60 volts
Baseline	-0.5 to +0.5 volts
Width	0.5 to 2.0 μ sec
Rise Time	0.15 μ sec max.
Fall Time	0.5 μ sec max.
impedence	75 ohms

50.3.5 System architecture for reliability.- The joint-use Mode S sensor shall achieve reliability through use of redundant elements as specified in 3.7.2 of the main body of this document and in Appendix III. In order to enhance reliability of Mode 4 operation Mode S switching shall be employed, as illustrated in Fig. V-1, to enable the AN/GPA-124 to operate with the spare front-end in the event that it replaces the Mode 4 on-line subsystem.

50.3.6 Interim Configuration A.- If required by the contract schedule, it shall be possible to install a joint-use sensor in an interim configuration using an antenna with a single front-face antenna. The back-face front-end will not be installed in the configuration. This interim sensor shall meet all of the requirements of a joint-use sensor specified herein except for the absence of data from the back-face.

It shall be possible to add the back-face front-end and a back-to-back back antenna system and meet all of the requirements specified herein for a complete joint use sensor without making any changes to the interim sensor components other than the modification of site adaptation parameters.

50.3.7 Interim Configuration B.- If required by the contract schedule, it shall be possible to install a joint use sensor in an interim configuration using a back-to-back antenna, such that one face is dedicated to FAA use and

the other face is dedicated to JSS use. The spare front end will not be installed in this configuration. If one of the front ends becomes inoperative, the single operative front end shall be dedicated to FAA use and JSS service will be interrupted. Remotely controlled reconfiguration shall allow reversing of this priority.

It shall be possible to add the spare front end and meet all of the requirements for the complete joint use sensor specified herein, without making any changes to the interim sensor components other than the modification of site adaptation parameters.

This space intentionally unused.

FAA-E-2716
APPENDIX VI

-VI-1-

APPENDIX VI

MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR VIDEO RECONSTITUTOR,
BACK-UP (ATC-BI) MODE,
AND SURVEILLANCE DATA SELECTOR

APPENDIX VI
MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR VIDEO RECONSTITUTOR, BACK-UP (ATC-BI) MODE, AND
SURVEILLANCE DATA SELECTOR

60.1. SCOPE

60.1.1 Scope.- This appendix specifies Mode S requirements necessary to render the sensor (1) capable of generating and outputting reconstituted video for display at an ATC facility using time-shared displays (e.g., ARTS-III DEDS) and on the Mode S sensor maintenance display, (2) capable of providing raw beacon video directly from the Mode S Interrogator-Processor to the ATC displays in the event of a Mode S sensor computer failure, and (3) capable of interfacing with a surveillance data selector that will select for transmission the output of the Mode S sensor or a colocated surveillance processor.

60.2. DEFINITION

60.2.1 Reconstituted video.- Reconstituted video is synthetic analog video, either beacon or primary radar, derived from Mode S digitized surveillance outputs.

60.3. REQUIREMENTS

60.3.1 Design requirements.- Unless otherwise specified in this appendix, the sensor modifications and additions shall meet all of the requirements specified in the body of this document.

60.3.2 Performance requirements.- A block diagram showing signal flow between the Mode S sensor, the Video Reconstitutor, and the ATC display system is shown in Fig. VI-1. This functional diagram is not binding upon the arrangement of the hardware.

60.3.2.1 Overall operation.- The video reconstitutor shall generate broadband beacon, radar and weather map video signals for output to a time-shared display such as the ARTS-III DEDS. The reconstitutor is an independent self-contained unit which may be located at the Mode S sensor or at the ARTS facility. The regenerated video signals shall be derived from the output surveillance messages originating at the Mode S sensor. Mode S surveillance messages disseminated to the reconstitutor shall be reconfigured into ATCRBS formatted messages containing an ATCRBS ID code in place of the Mode S address.

The video reconstitutor shall have the capability of outputting either ATCRBS Mode 3A or Mode C reply video as specified in the Mode S National Standard, (i.e., all beacon reply pulses), or a beacon position slash for each bracket pair detected. The video reconstitutor shall have the capability of adding a site adaptable magnetic variation to the azimuth contained in the surveillance messages received from the sensor prior to outputting video position symbols to the displays. An ATCRBS beacon decoding function shall be provided in accordance with Appendix VI-A if specified in the contract schedule.

In addition to the digital surveillance message inputs, the reconstitutor shall be able to accept an external radar pretrigger for generation and output of time coincident beacon and radar display synch triggers, and an ATCRBS Mode identifier to indicate the reconstitution of either Mode 3A or Mode C video. The reconstitutor shall also accept external ACP and ARP signals from either the ASR directly, or from a video delay unit. If the ACP/ARP signals are derived from the ASR, the video reconstitutor shall delay the signals to be coincident with the azimuth position of the reconstituted video. If the ACP/ARP signals are derived from an external video delay unit in which coincidence has been established, the reconstitutor shall regenerate the signals without delay.

In the event that neither a radar pretrigger nor ARP and ACP's are externally available, the reconstitutor shall have the capability of internally generating beacon and radar pretriggers and ACP/ARP signals for output to the display system.

A capability shall exist for displaying both target reports and sensor status as well as the video output of the reconstitutor on a performance/maintenance display located either at the sensor site or at the ATC facility.

In the event of a Mode S sensor computer failure, a back-up mode or ATC BI mode of operation shall be provided in which defruited ATCRBS beacon sum video

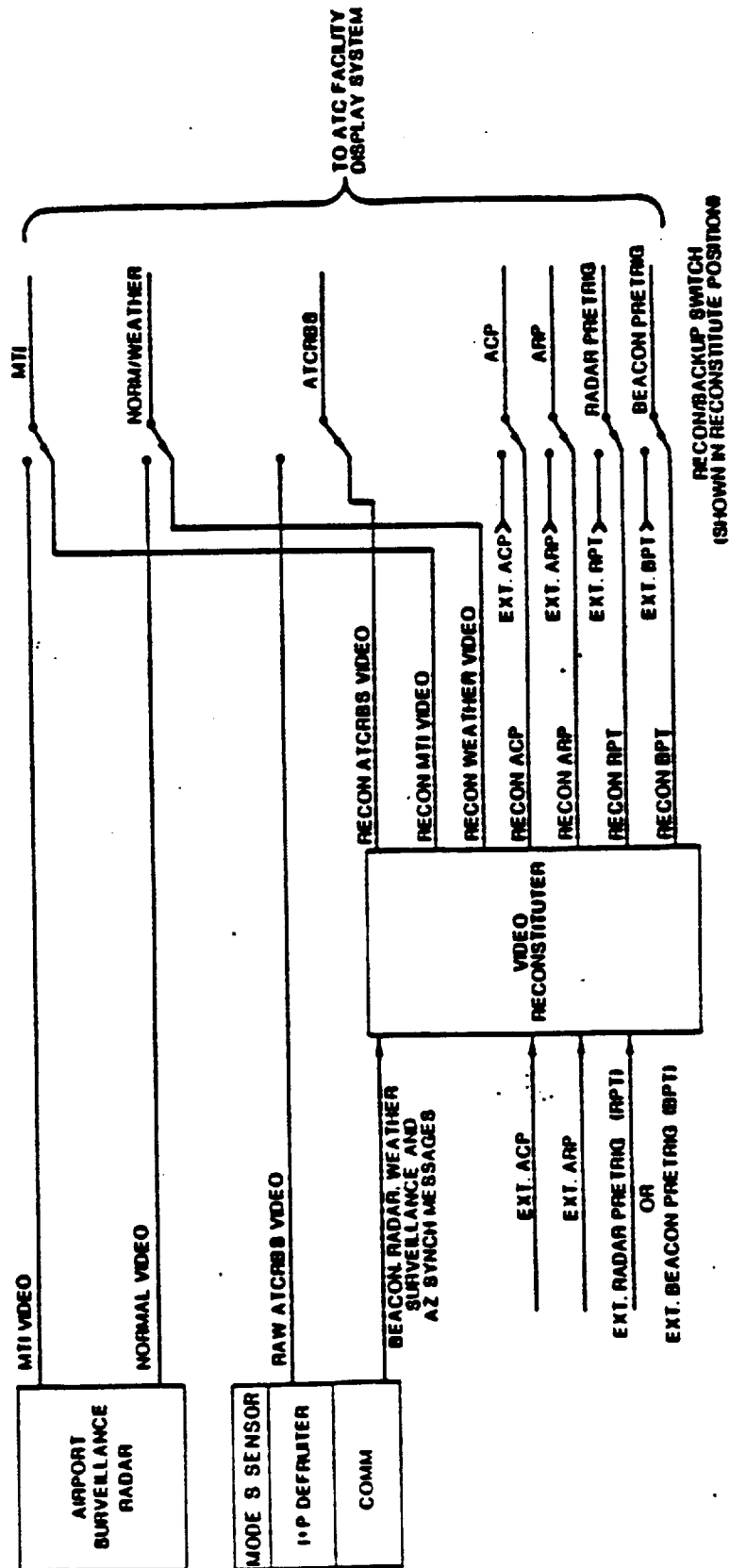


Figure VI-1 Video Reconstitutor and Interface Block Diagram

signals are made available to an ARTS display. In this mode of operation the Mode S interrogator and processor shall operate in an ATCRBS mode independent of channel management to provide pre-arranged staggered and mode interlaced transmissions relative to externally or internally generated pretriggers. The reconstitutor shall be bypassed and raw video, as specified in 3.4.3.5.4 of the body of this specification, substituted by the operation of a single switch. An MX-8757 digital defruiter will be provided by the Government to perform the defruiting function.

60.3.2.2 Video delay.- The reconstituted video may be delayed to the extent required to provide representative target azimuth extents. The maximum delay under peak aircraft loading conditions from antenna boresight of target to output of video reconstitutor shall not exceed 2.0 seconds.

60.3.2.3 Range accuracy.- The overall (system) range accuracy at the output of the video reconstitutor shall be within 1/16 nmi rms for radar reports, 1/16 nmi rms for beacon reports and 1/2 nmi rms for weather map data.

60.3.2.4 Azimuth accuracy.- The overall (system) azimuth accuracy at the output of the video reconstitutor shall be no greater than 0.16 degrees rms for both beacon and radar reports.

60.3.3 Back-up (ATC-BI) mode.- When ATCBI backup is selected, the time for ATCBI backup to become active shall be less than 100 msec. When return from ATCBI backup is selected, the time for non-ATCBI backup to become active shall be less than 100 msec. Notification of ATCBI backup selection and return from ATCBI backup selection shall be made available at the RMS output within 1.0 seconds from the time of the selection or return.

60.3.3.1 Modulation control unit.

60.3.3.1.1 Transmission control.- The Modulation Control Unit (MCU) shall receive the input information specified in 3.4.2.1 of the body of this document for each transmission. It shall compare the state of the station clock to the specified transmission time using the transmission control register, and generate an interrogation. In the event of a computer system failure the MCU shall generate an interrogation at a time relative to a beacon pretrigger as specified in 60.3.3.1.2 and 60.3.3.1.3.

60.3.3.1.2 Stagger operation.- The MCU shall have the capability of staggering the interrogation pulses, referenced to the beacon pretriggers, for cancellation of second-time-around replies. The staggering shall be done in a prearranged sequence of 0, +3.6, and +7.2 microseconds relative to the beacon pretrigger. The following five-step stagger sequence shall be used: 7.2 microseconds; 0 microseconds; 3.6 microseconds; 3.6 microseconds; and 0 microseconds. Destaggering circuitry shall be provided to realign the video replies and stagger mode triggers, by delaying these signals either +7.2, +3.6, or 0 microseconds to make the total delay equal to 7.2 microseconds (the sum of the stagger and destagger times). The accuracy of the individual delays shall be ± 0.025 microseconds.

Realigned video and mode triggers shall be time aligned within ± 0.025 microseconds referenced to the resynchronized Beacon Pre-trigger. The Beacon Pre-trigger shall be resynchronized to the system 16 MHz clock with provisions to prevent metastable conditions.

Front panel controls shall be provided to activate or disable the stagger operation. In the stagger off condition, the transmitted mode triggers shall be delayed 7.2 microseconds and the video replies and destagger mode triggers shall be delayed 0 microseconds. Alternate stagger control provisions will be considered. The stagger operation shall be automatically disabled during Mode 4 operation.

60.3.3.1.3 Auto interlace operation.- In the event of a complete computer system failure, the MCU shall have the capability of generating transmissions without channel management control. Three separate mode intervals, designated X, Y, and Z, represent time intervals between beacon pretriggers during which any of the 3 modes (2, 3/A, C) may be transmitted. The MCU shall have separate mode selection switches for each designator interval to permit different mode interrogation during each interval. In addition, the MCU shall have an interlace selection control to permit selecting various patterns of interlacing the designator intervals. Seven patterns that can be selected shall be: continuous X, continuous Y, continuous Z, XXYX..., XXXXY..., XYXYZ..., YXXZXXZ... patterns.

60.3.3.1.4 Pretrigger generator.- The sensor shall be capable of generating pretriggers to be used in synchronizing ATCRBS transmissions in the event of a Mode S sensor computer failure. The pretrigger source shall be selectable and one of the following:

- (a) Radar pretrigger. When a radar pretrigger is available it shall be used to generate the beacon pretrigger.
- (b) Internal mode. If a radar pretrigger is not available, the sensor shall generate an internal beacon pretrigger. The PRF in the internal mode shall be adjustable between 150 and 450 pulses per second.

60.3.3.1.5 Back-up (ATC-BI) mode output requirements.- The Mode S contractor shall provide all controls, switching equipment, cabling and other components necessary to interface both channels of the dual channel Mode S system when operating in Back-up (ATC-BI) mode with the remoting equipment and external equipment specified herein. Each channel shall provide the following:

- (a) Four quantized video outputs as specified in 3.4.3.5.4. The outputs from each channel shall be routed and switched by the control and switching equipment. After switching, each of the 4 quantized videos shall be independently adjustable. Each output shall be electrically isolated so that a short or failure in one output shall not affect the other outputs. Each quantized auxiliary video output shall have the following characteristics:

Amplitude:	+1.0 to +5.0 volts, adjustable
Baseline :	0.0 ± 0.1 volts
Rise time:	100 nanoseconds, maximum
Fall time:	100 nanoseconds, maximum
Impedance:	75 ± 5 ohms

Overshoot and undershoot on the video pulses shall be less than 5 percent. Noise signals shall be less than 0.1 volt over the full output adjustment range.

- (b) Five separate, isolated beacon sync trigger outputs. Three of these outputs from each channel shall be routed and switched by the control and switching equipment. One of the unswitched outputs from each channel shall be used for defruiter synchronization.
- (c) The following isolated mode trigger outputs comprising P1 and P3 pulses from each channel shall be routed and switched by the control and switching equipment.
 - (1) Four sets of destaggered mode triggers.
 - (2) One set of unswitched staggered mode triggers.
- (d) The triggers specified above shall have the following characteristics:
 - (1) Polarity: Postive
 - (2) Pulse amplitude: Selectable 25 volts ± 1 volt or 15 volts ± 1 volt.
 - (3) Pulse Duration: 1.0 ± 0.5 microseconds.
 - (4) Pulse Rise Time: 0.1 microseconds maximum.
 - (5) Pulse Decay Time: 0.4 microseconds maximum.
 - (6) Pulse jitter, with respect to the radar input trigger: 60 nanoseconds maximum.
 - (7) Baseline: ± 0.1 volts
 - (8) Pulse Width: 1.0 microseconds, - 0.5 and + 1.0 microseconds
 - (9) All trigger outputs shall have a source impedance of 75 ohms or less and shall be designed to drive a properly terminated 75 ohm coaxial cable. Each output shall be sufficiently isolated such that improper terminating impedance, including shorts and opens shall not affect system operation.
- (e) Each channel shall provide two separate BNC jacks for accepting radar zero and pre-trigger.

60.3.3.2 Surveillance processing.

60.3.3.2.1 Surveillance data dissemination. - The data dissemination function shall format beacon reports. These reports shall be selectively disseminated to the ATC facility based upon area-of-responsibility rules specified in 3.4.6.14 of the body of this document. Also, in the reconstituted video mode, data dissemination shall specify that all disseminated ATRBS beacon reports, radar only reports, and radar substituted reports shall be sent to both the surveillance port specified for reconstituted video and to all appropriate ATC facilities. The appropriate ATRBS report or radar report format shall be used in these disseminations. In addition, dissemination shall disseminate all Mode S beacon reports twice. The first dissemination shall be in the Mode S beacon report format and shall be to all appropriate ATC facilities, and the second dissemination shall be only to the surveillance port specified for reconstituted video and shall be in the ATRBS beacon report format.

The surveillance port specified for the reconstituted video shall be defined so as not to interfere with the primary dissemination function to other users. All data which is to be disseminated to at least one ATC facility or external sensor, as determined from the dissemination lookup table (3.4.6.14.3 of the body of this document), shall be disseminated to the video reconstitutor.

This space intentionally unused

In disseminating data to the reconstitutor, the dissemination function shall format all beacon reports in the ATCRBS beacon report format per 3.4.6.14.3 of the body of this document. Thus, dissemination shall be required to:

- (a) Set the dissemination bit in the destination word of each ATCRBS report to include dissemination to the reconstituted video data line.
- (b) Disseminate Mode S reports per 3.4.6.14.3 of the body of this document.
- (c) Reformat Mode S beacon reports in the ATCRBS beacon report format and to disseminate these reports only to the reconstituted video data line (only the dissemination bit for the reconstituted video line shall be set in the destination word of these reports).
- (d) Limit all reports thus disseminated to the reconstitutor to a maximum target range defined via a site adaptable parameter.

60.3.3.3 Network management.- Every time a transition into status S4 occurs, the flag OSE in the out-list shall be checked. If OSE = 1, signifying the entry belonged to the request outstanding list, it shall be reset to 0 and a data start message shall be issued to the sensors listed there. Every time a transition into S4 occurs (specifically a transition S1-S4, S3-S4) the request bits TR, TRR, and IR shall be checked. Bit TR shall be set to 0. If TRR = 0 and IR = 0, a cancel request message shall be issued to the sensors listed in the in-list (if any) (see also 3.4.8.9.2 of the main body of this specification. If TRR = 1 or IR = 1, no further action shall be taken. A transition into S4 shall always trigger a lockout control state assignment procedure, a determination of ATCRBS ID code, and a determination of cata-link capability. Each of these procedures shall be executed as in 3.4.8.7.3.3 of the main body of this specification.

Note: the request for ATCRBS ID is required to ensure that the ATCRBS ID is available in the surveillance file for use by surveillance formatting and dissemination in the dissemination of Mode S beacon reports to the video reconstitutor.

60.3.3.4 Performance monitor/maintenance display.

60.3.3.4.1 Description.- The performance monitor/maintenance display shall include a Plan Position Indicator (PPI) mode in which all target reports and an alphanumeric tabulation of sensor status reports are displayed. For digitized target presentation the display shall be connected to the digital side of the modems for the ground communications lines linking the sensor with the served ATC facilities. For raw video presentation the display shall be connected to the reconstitutor output. This display mode is primarily intended

for implementation at the sensor site, but the capability for operation at the equivalent output point of the ATC located modems shall be possible if desired. Operation at the ATC facility shall be accomplished without modification to the display or the ATC equipment.

60.3.3.4.2 Inputs.- The inputs to the monitor display shall consist of:

60.3.3.4.2.1 Digital inputs.-

- (a) The stream of sensor surveillance and communication output messages as specified in 3.5.3.1 and 3.5.3.3 of the main body of this specification, intercepted at a digital level at the input to the modems for the ground communication and surveillance data distribution interfaces.
- (b) Commands entered from the keyboard.
 - (1) Display sensor status report
 - (2) Vary range
 - (3) Off-center display
 - (4) Select a subset of targets for display according to target type (i.e., ATCRBS, Mode S, radar) or according to altitude band (i.e., between specified minimum and maximum altitudes) or both.
 - (5) Delete/add identity and altitude tag on Mode S or ATCRBS targets.

60.3.3.4.2.2 Radar inputs.-

- (a) Video inputs (MTI, NORMAL, Beacon) - 1 to 8 volts positive
- (b) ACP (4,096), ARP (north) - 4 to 6 volts positive
- (c) Radar pretrigger - 2.5 to 75 volts positive, 20 to 120 μ sec prior to zero time.
- (d) Beacon pretrigger - 2.5 to 75 volts positive, 20 to 120 μ sec prior to zero time.

(e) Commands entered from the keyboard, specifically:

- (1) Range selection (same as digital range switch)
- (2) Selection of RADAR, alphanumeric or time-share modes of operation.
- (3) Selection of test mode instead of "2", above.
- (4) Off centering the display (by hardware, one radii only in raw video mode).

60.3.3.4.3 Outputs.- The output shall consist of a visual display on a CRT whose dimensions are at least 20 inch useful diameter. In addition, there shall be red, yellow, and green lights for sensor status and two audible alarms for red and yellow condition.

The outputs shall be compatible with the requirements of the Mode S sensor maintenance display (3.4.10.4 in the body of this document) as modified by the following paragraphs.

60.3.3.4.3.1 Synthetic presentation.- The PPI shall have its center at the sensor site and shall have unique symbols for Mode S, ATCRBS, radar, and test (CPME) targets. Reinforced beacon targets shall be shown with a superimposed radar symbol. Radar substitution reports shall be shown with a dot symbol super imposed on the appropriate beacon target symbol. Beacon targets shall be tagged with ID and altitude as selected at the operator's option. The symbols for any target report shall remain visible for a time interval slightly less than the antenna scan period.

Alphanumeric data pertaining to sensor status shall be displayed concurrently with the PPI in a reserved region of the CRT. In the event of red or yellow sensor condition, status reports shall automatically be presented in a self-explanatory form.

60.3.3.4.3.2 Raw video or time-share presentation.- The raw video presentation mode shall consist of the following data presented separately or time-shared with the synthetic data depending on the mode selected.

- (a) Video presentation - MTI, NORMAL or range gated MTI/NORMAL, BEACON.
- (b) RANGE MARKS - 2, 5, 10, 20 and 50 nmi, every 5th mark intensified.
- (c) Time-share - video (a and b above) with 100 full data blocks.

The above video presentation shall be provided with display ranges of 7.5, 10, 15, 20, 30, 40, 60, 80, 160, and 260 nmi. The primary radar video shall be gated off after 60 nmi to avoid displaying successive sweeps at greater than 60 nmi.

60.3.4 Video reconstitutor.

60.3.4.1 General description.- The video reconstitutor shall convert certain Mode S FAA-RD-80-14 surveillance messages to the conventional rho-theta 60 nmi PPI video. It shall be an independent self-contained unit that can be located at the Mode S sensor or at the ARTS ATC facility. The unit shall provide ATCRBS reply pulses for both Mode S and ATCRBS targets for Modes 3/A and C responses. Primary radar reconstitution shall be displayed via the "MTI" ARTS time-shared display channel for target messages and "normal" ARTS time-shared display channel for weather messages so that the background video gain control on the display can be used to adjust weather presentation levels.

60.3.4.2 Reconstitutor inputs.

60.3.4.2.1 ACP and reference pulse.- In the beacon reconstitution mode, i.e., when operating with the primary radar video delay and thus without a primary radar digitizer, the video reconstitutor shall accept and operate with ACP and reference pulse outputs from the video delay unit or from the primary radar/Mode S sensor. External ACP and ARP inputs to the video reconstitutor are only required when operating without a primary radar digitizer.

60.3.4.2.2 Reconstitutor input formats.- The video reconstitutor shall accept the ATCRBS, search and map surveillance messages as input data for conversion to 60 nmi rho-theta video. The reported range and azimuth shall be used as the target location. The other surveillance formats shall not be transmitted to the reconstitutor in order to preserve line capacity. All Mode S messages are input as ATCRBS messages from the sensor. Target reports exceeding a delay of $\frac{3}{8}$ of a scan shall not be used by the reconstitutor. This means that the Mode S throughput, including transmission delays, to the video reconstitutor shall be equal to, or less than, 12 sectors even under peak aircraft loading conditions.

60.3.4.3 Reconstitutor outputs.- The video reconstitutor shall provide 60 nmi rho-theta ATCRBS, radar and map video signals synchronized to regenerated mode triggers, pretriggers, ACP's and azimuth reference pulse. Each output shall be an isolated output with line driver and remote line receiver. The line receiver video output impedance shall be 91 ohms. Video reconstitutor communications capacity shall be required to meet the sensor peak loading and maximum delay requirements. Reconstitution of messages shall be as follows:

- (a) ATCRBS only - Alternate 3A and C reply pulses or 3A pulses only per the Mode S National Standard and at the range and azimuth specified in the input message.
- (b) ATCRBS reinforced - 3A and C reply pulses and radar pulses at the range and azimuth specified in the input message.

- (c) ATCRBS substituted - substituted radar pulses only.
- (d) RADAR only - Radar pulses at a selected range and azimuth extent or a binary fraction of the selected extents, dependent upon the contents of the message. Specifically, messages representing tracked radar targets (Category 1) shall result in the full range and azimuth extent selected. Messages representing untracked radar targets shall be placed in one of four categories (2A through 2D) and result in an output at a binary fraction of the selected range and azimuth extent (initial design fraction shall be 1/2). A maintenance selectable option capability shall be provided as follows:

<u>DISPLAYED</u>	<u>CATEGORY</u>	<u>SFN</u>	<u>QUAL</u>	<u>CONF</u>
Category 1 (only)	1	Yes	-	-
Category 1 and 2A (only)	2A	No	High	High
Category 1, 2A and 2B (only)	2B	No	High	Low
Category 1, 2A 2B and 2C (only)	2C	No	Low	High
Category 1, 2A 2B, 2C and 2D	2D	No	Low	Low

- (e) MAP -two levels of video. Pulse starts at "range start" and ends at "range stop" for a 16 ACP azimuth extent.
- (f) MILITARY IDENT - Like (a) or (b) with SPI pulse generated 4.35 usec following the F2 pulse if the SPI bit is set in the input message.
- (g) MILITARY EMR - Like (a) or (b) with 7700 information pulses.
- (h) Capability to switch operation of the video reconstitutor output (a) and (b) such that the ATC display can be operated without a 1212 decoder or without the decoder specified in Appendix VI-A. In this case, a single slash shall be output for each bracket pair. An additional slash for SPI shall be generated when applicable.
- (i) Capability to provide a beacon decoding function (Appendix VI-A).

60.3.4.3.1 Output pulse characteristic.- The ATCRBS video pulse amplitude shall be 2 to 4 volts positive for radar outputs and 1 volt min. (adjustable) for beacon output and the video rise and fall times shall be as specified in the Mode S National Standard. The ATCRBS video output shall be selectable not to alternate between 3/A and C, but to output 3/A only.

The radar video pulse amplitude shall be 2 to 4 volts positive, and the video rise and fall times shall be 0.2 usec max.

Weather map video amplitude shall be between 0.8 and 1.2 volts for the low level and between 1 and 4 volts for the high level. Video rise and fall times shall be less than 0.2 μ sec.

60.3.4.4 Pretrigger generation.- The video reconstitutor shall be capable of generating pretriggers to be used in synchronizing the output video with the display equipment. The pretrigger source shall be selectable to be one of the following.

- (a) Radar pretrigger. When the radar pretrigger is selected as the timing source, its PRF shall be divided by 3 to become the beacon sync trigger. A beacon mode trigger pair and beacon video shall be generated in synchronism with the beacon sync trigger.
- (b) Beacon pretrigger. When the beacon pretrigger is selected as the timing source, a beacon sync trigger shall be generated coincident with the beacon pretrigger. A beacon mode trigger pair and beacon video shall be generated that are synchronous with the beacon sync trigger.
- (c) Internally generated. The video reconstitutor shall be capable of generating a radar pretrigger coincident with each externally or internally generated ACP signal. When this source is selected, the beacon synch trigger, the beacon mode trigger pair, and the reconstituted beacon video shall be generated in synchronism with, and at the rate of, the internally generated radar pretrigger.

60.3.4.5 Mode trigger output.- A P1-P3 mode trigger pair shall be generated on an output line separate from the beacon video lines. The delay from beacon sync trigger to P3 shall be adjustable between 21.5 and 150 microseconds. The delay between P1 and P3 shall be set to indicate if mode 3A and mode C video is being reconstituted. A simple internal means shall be provided to enable and disable the mixing of the beacon trigger with the mode trigger pair.

60.3.4.6 Output pretrigger level.- The pretrigger level shall be 20 ± 10 volts with positioning adjustable between 50 to 125 microseconds prior to zero range.

60.3.4.7 Internally generated ACP/ARP.- In the event that external ACP/ARP's are not available, the video reconstitutor shall be capable of internally generating ACP/ARP signals. The internally generated ACP/ARP's shall be synchronized to the reconstituted video azimuth based upon the azimuth position information contained within a special synch message received once per scan via the modem data link. The synch message format shall be identical to a search message. The interval between generated ACP's shall range between 500 and 2000 μ sec with a resolution of 10 μ sec max. An ARP shall be generated every 4096 ACP periods with its nominal midpoint between two ACP pulses.

-VI-13-

60.3.4.8 Target azimuth and range extent.- The ATCRBS and radar target azimuth extent shall be separately maintenance-selected between 10 to 26 sweeps at each of their respective PRF's. The range extent of the radar pulses shall be maintenance-adjustable between 0.77 to 2.31 useconds in 0.77 useconds steps.

60.3.4.9 Video switching provisions.- The video reconstitutor shall provide video switching capability to select between reconstituted video in the normal mode, and raw beacon and radar video in the back-up mode. This shall consist of the following:

- (a) Switching between raw and reconstituted ATCRBS video and triggers.
- (b) Switching between raw and reconstituted primary radar video and trigger (MTI video).
- (c) Switching between raw and reconstituted map video (Normal video).
- (d) Switching between raw or reconstituted azimuth reference and azimuth change pulses.

60.3.5 Interfaces/data links.

60.3.5.1 Mode S sensor to reconstitutor link.- The sensor-to-reconstitutor link shall have the same characteristics as the sensor to ATC facility surveillance link specified in para. 3.5.3.2 of the body of this document.

60.3.5.2 Azimuth data.- When operating without a radar digitizer, the reconstitutor shall be provided with real time ACP and ARP data from either the radar, or the video delay unit. ACP input shall be 4096 ACP's per antenna revolution.

60.3.6 Surveillance data selector.- The contractor shall provide, in accordance with the contract schedule, a surveillance data selector to be used when the Mode S equipment is colocated with another surveillance processor. The surveillance data selector shall provide the capability to select for transmission to the indicator sites either the Mode S surveillance data outputs or those of a colocated surveillance processor.

The following two modes of operation shall be provided. The mode of operation in effect shall be determined by a site adaptable parameter.

- (a) Operational mode one: when the Mode S sensor is not failed, the selection of the Mode S surveillance data shall be the normal mode of operation. In the event of Mode S sensor failure, the colocated surveillance processor output data shall be selected for transmission to the indicator sites.
- (b) Operational mode two: when the colocated surveillance processor equipment is not failed, the selection of the colocated surveillance processor surveillance data shall be the normal mode of operation. When the colocated surveillance processor equipment fails and the

Mode S sensor is not failed, the the Mode S surveillance data shall
be selected. In the event of Mode S sensor failure, the colocated
surveillance processor output data shall still be selected for
transmission to the indicator sites. #

The output of the Mode S sensor shall be designed to operate either into the
surveillance data selector or directly to the government modems. The same
modems will be used whether the Mode S sensor is connected directly to them
or from the surveillance data selector. The surveillance data selector shall
be capable of handling a minimum of three modems. #

The capability for data (Mode S or colocated surveillance processor)
selection shall be provided both at the local (Mode S) and at the indicator
site. #

The sensor shall be able to support multiple surveillance data selectors.
This will allow multiple data selectors to be used when there are more modem
connections feeding indicator sites than the capacity of one surveillance
data selector. All surveillance data selectors shall be activated by the same
control command, and shall all switch to the same data source. #

This space intentionally unused.

FAA-E-2716
APPENDIX VI-A

-VI-A-1-

APPENDIX VI-A

MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR BEACON DECODER TO BE USED WITH
THE MODE S SENSOR VIDEO RECONSTITUTOR

APPENDIX VI-A

MODE SELECT BEACON SYSTEM SENSOR

REQUIREMENTS FOR BEACON DECODER TO BE USED WITH
THE MODE S SENSOR VIDEO RECONSTITUTOR

60.A.1. SCOPE

60.A.1.1 Scope.- This appendix specifies a beacon decoder to be used with the Mode S sensor Video Reconstitutor.

60.A.2. DEFINITION

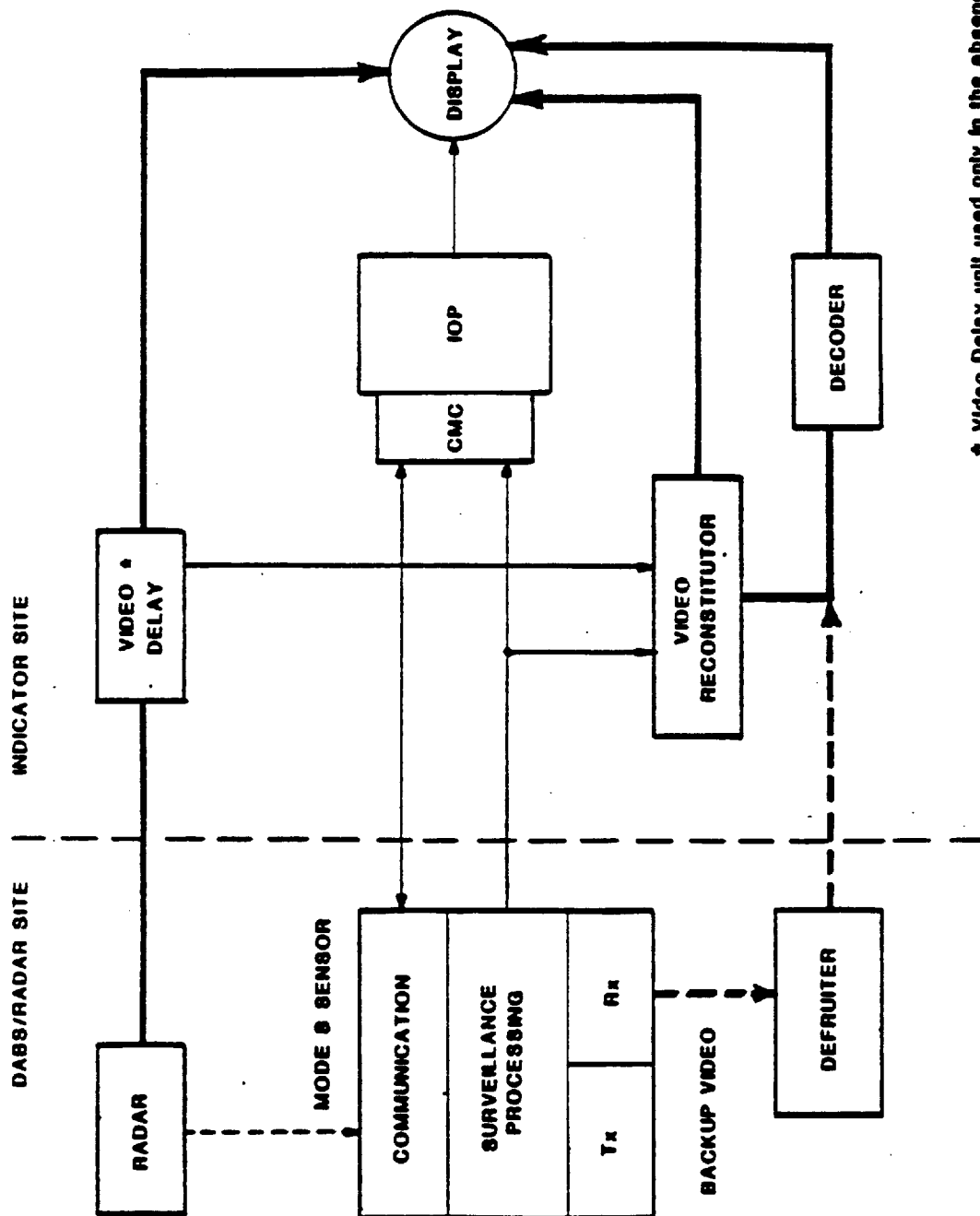
60.A.2.1 Beacon decoding.- Beacon decoding is the identification, by discrete symbols on operational ARTS displays, of those aircraft which are transmitting selected beacon codes.

60.A.3. REQUIREMENTS

60.A.3.1 Design requirements.- Unless otherwise specified in this appendix, the beacon decoder specified herein shall meet all of the requirements specified in the body of this document.

60.A.3.2 Performance requirements.- A block diagram showing signal flow between the Mode S sensor, the video reconstitutor/beacon decoder and the ATC display is shown in Fig. VI-A-1. The functional diagram is not intended to be all encompassing nor is it intended to be binding upon the exact arrangement of the hardware.

FIGURE VI-A-1



* Video Delay unit used only in the absence of a terminal radar digitizer.

FIGURE VI-A-1 MODE S/ARTS LIA CONFIGURATION

60.A.3.2.1 Mode decoding.- The beacon decoder specified herein shall extend the capability of the video reconstitutor to provide for decoding beacon codes. The combined video reconstitutor/decoder functions shall identify, by distinct video symbology on operational ARTS displays, aircraft which are transmitting selected codes. Provision shall be made to recognize up to 10 selected Mode 3/A, 4096 ATRBS codes and three special codes. Outputs shall be provided for up to 11 individually controlled displays. Controls for selection of codes, and the specific format on the display, are specified below.

60.A.3.2.1.1 Code selection box.- There shall be one code selection box whereby 10 selected beacon codes may be entered. These codes shall be code compared with the incoming beacon message codes. The box panel lay-out shall be similar to Figure VI-A-2. The code switches shall be backlit, thumbwheel type switches.

60.A.3.2.1.2 Code type selection.- A two position toggle switch shall be provided adjacent to, and associated with, each code select switch assembly. The toggle switch shall select the portion of the selected beacon code to be used for code comparison. In one toggle position, the A and B portions of the selected code shall be used for comparison with the incoming beacon code data (non-discrete code), and the C and D bits shall be ignored. In the other toggle position, the selected A, B, C and D code bits shall be used for comparison with the incoming beacon code data (discrete codes). Channel 1 on the code select box (Fig. VI-A-2) shall be designated as a special function channel (3.2.1.5.1).

60.A.3.2.1.3 Emergency alarm.- Visual and audible alarm indicators shall be activated when an emergency, communications failure, or hijack code is detected for a predetermined number of reports. The detection criteria shall be wirestrap adjustable from M=1 to 3 reports out of a total of N=0 to 4 reports. Logical protection shall be provided to alarm on one report if M exceeds N. A momentary switch shall be provided to reset the alarm for a period adjustable between 30 seconds and 3 minutes. If the condition causing the alarm persists, or a new emergency is sensed at the end of the reset period, the alarm shall again be energized.

60.A.3.2.1.4 Physical characteristics.- The code select box shall be mountable in the vertical or near vertical panel of an existing ARTS display console. Maintenance of the code select box shall be performed from the front side of the mounting panel. Cabeling shall enter the box from the rear via a cable connector. The box shall be designed so that the physical dimensions do not exceed 12 inches in length and 10 inches in width and 6 and 1/2 inches in depth.

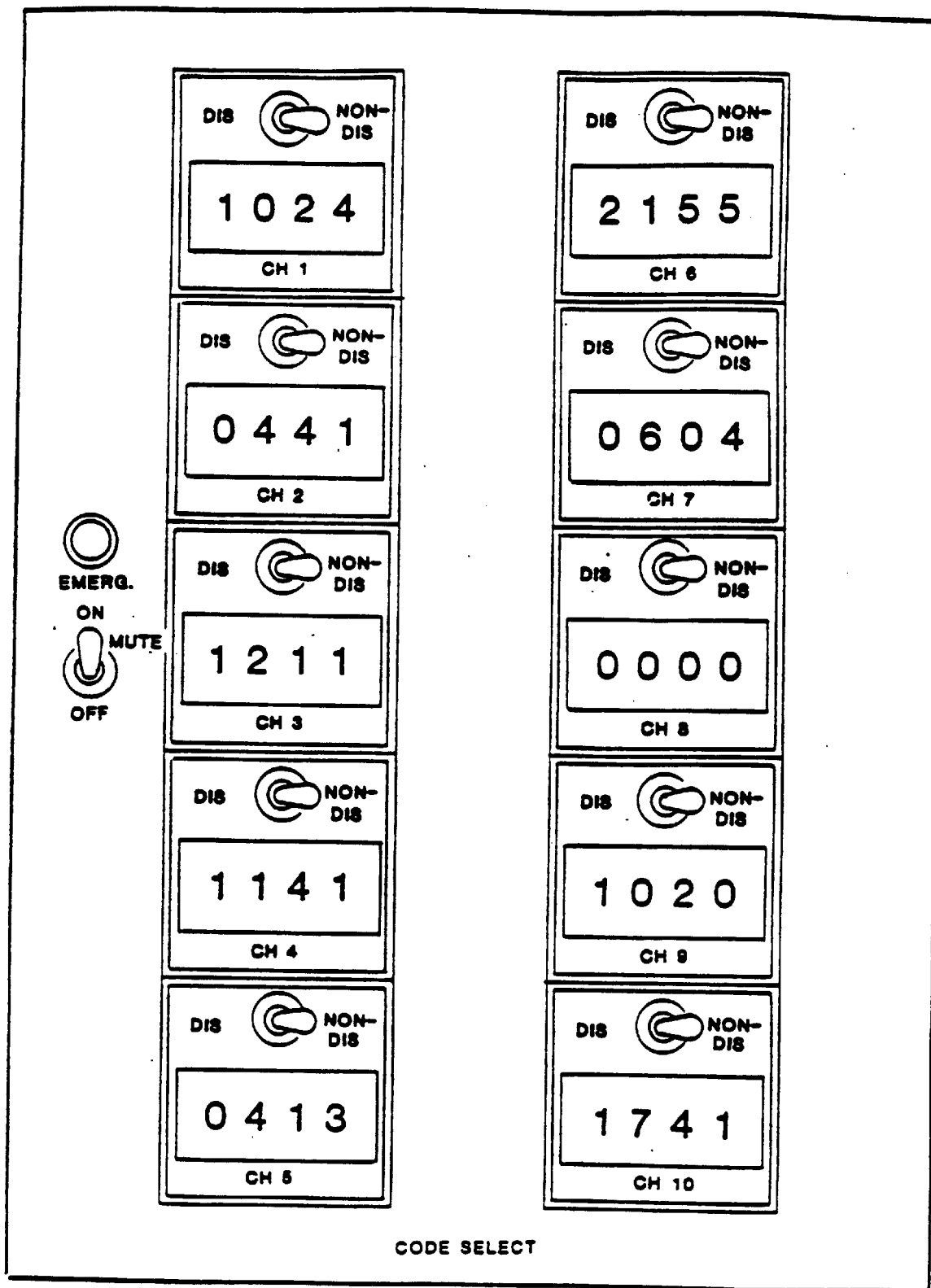


FIGURE VI-A-2 CODE SELECT PANEL

60.A.3.2.1.5 Display control boxes.- There shall be a single display control box located with each display. The display control box shall control the type of display format on its associated display. The display control box front panel layout shall be similar to Figure VI-A-3. Each box shall have 12 switches. The function of each switch is specified in the following paragraphs. All switches on the display control box shall be backlighted. A backlighted, plexiglass strip shall be provided beside the code display selection switches. The strip shall provide for manually writing the codes set into the code select box on the Display Control Box. Amber lamps shall be mounted between each switch and the plexiglass strip to indicate selection of a discrete code on the Code Select Panel. In addition, special marking shall indicate the special function characteristics on Channel 1.

60.A.3.2.1.5.1 Selectable codes.- The Display Control Box shall enable the use of the codes entered on the code select box. Ten three-position (ID-SEL-OFF) switches shall be provided, each corresponding to the similarly positioned code on the code select box. The ten three-position switches shall operate in conjunction with the two-position (C/S-OFF) Common-System switch to govern the format generated on the display. The Common-System switch shall exhibit control over the ten three-position code selection switches as follows:

With the Common-System switch in the C/S position:

1. OFF position - All beacon targets shall be displayed by a single slash.
2. SEL position - All beacon targets shall be displayed by a single slash.
3. ID position - All beacon targets on that display having the selected code shall be displayed as a double slash, except targets having the code of Channel 1 which, when selected, shall display a triple slash. A target with that code, responding with an SPI identifier, shall be displayed as a single bar (bloomer), except targets having the code of Channel 1 which shall be displayed as a single bar and a slash. All other beacon targets in the Common-System shall be displayed as a single slash.

With the Common-System switch in the OFF position:

1. OFF position - All beacon targets shall be inhibited.
2. SEL position - All beacon targets on that display having the selected codes shall be displayed as a single bar (bloomer). No other targets shall be displayed.

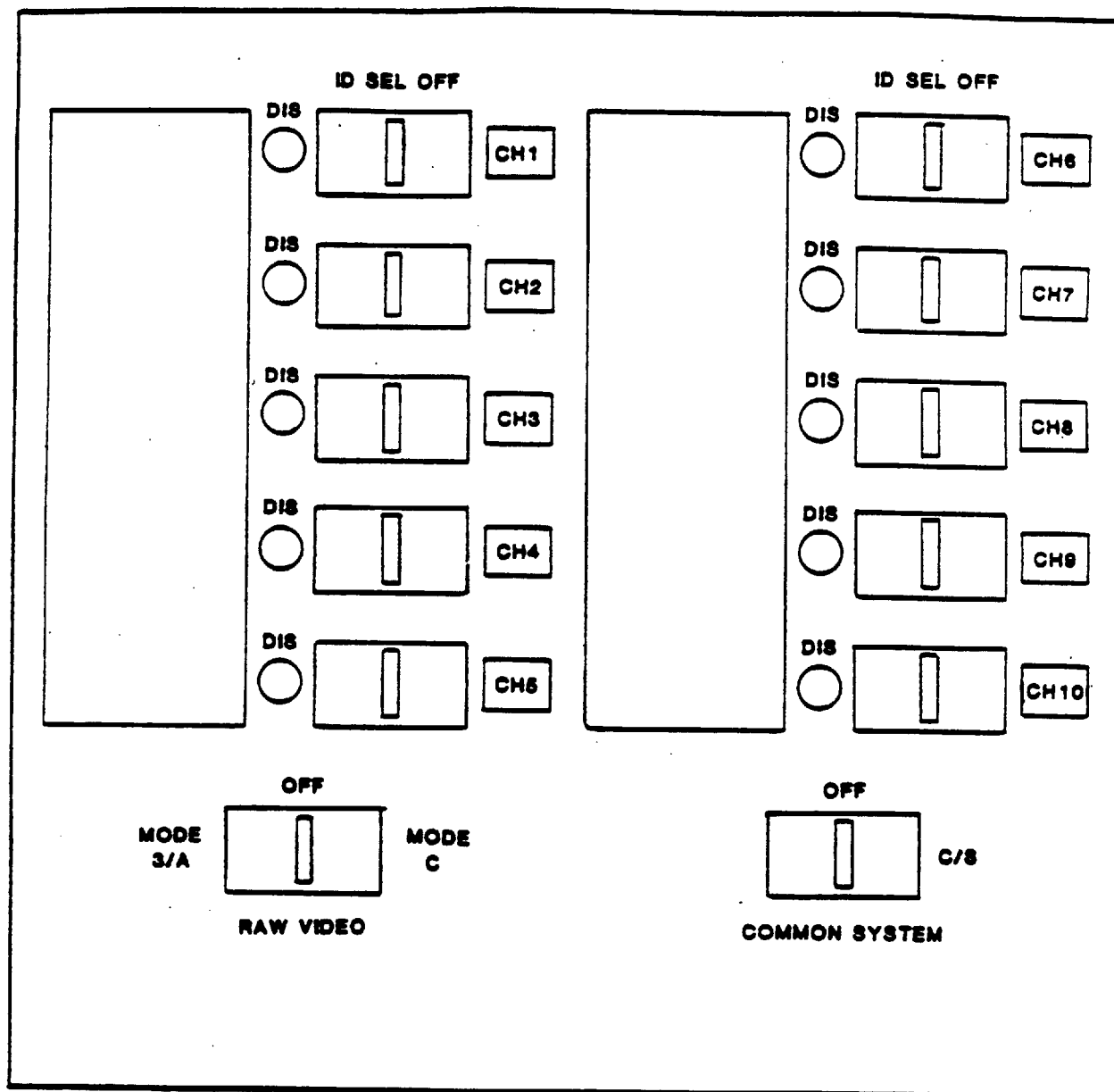


FIGURE VI-A-3 DISPLAY CONTROL PANEL

3. ID position - All beacon targets on that display having the selected code shall be displayed as a double slash, except targets having the code of Channel 1 which, when selected shall be displayed as a triple slash. A target that responds with the SPI identifier shall be displayed by a single bar (bloomer), except targets having the code of Channel 1 which shall be displayed as a single bar and a slash. No other targets shall be displayed.

60.A.3.2.1.5.2 Special codes.- The analog decoder shall recognize three special discrete beacon codes and generate unique display symbols for these codes independent of the display control box switch settings. The three special codes and their unique display symbols are specified below:

1. 7700 Reply - The emergency code, 7700, when received, shall cause a double bar (double bloomer) to appear on all displays.
2. 7600 Reply - The radio communication failure code, 7600, when received, shall cause a filled-in double bar (wide bloomer) to appear on all displays.
3. 7500 Reply - The 7500 code, when received, shall cause a double slash, followed by a bloomer, to appear on all displays.

60.A.3.2.1.5.3 Raw video.- The display control box shall have an additional three-position (Mode 3A-OFF-MODE C) switch used to select the display of the video. With the raw video switch in the Mode 3A position, only Mode 3A replies are displayed. The selection of raw video shall override the generation of code selected video formats, and the incoming beacon video shall be presented to the display. The F-1 pulse shall represent target range.

60.A.3.2.1.5.4 Physical characteristics.- The display control box shall be designed to be as small as practical, not to exceed 8 inches long, 7 inches wide, and 6 1/2 deep, to be mountable in either a vertical or near vertical panel of an existing console, or to be used as a table-top device. Vertical-mounting shall be used by vertical displays. Table-top mounting shall be used with horizontal displays or display positions not having convenient vertical-mounting facilities. When vertical-mounting is utilized, maintenance shall be performed from the front side of the mounting panel and the cabling shall enter the box from the rear via a cable connector.

60.A.3.2.1.6 Display format.- The reconstitutor/decoder shall generate seven unique display patterns, as illustrated in Figure VI-A-4. When Mode 3/A and Mode C interlacing is used, the display video generator shall inhibit the generation of Mode C targets and it shall generate patterns from the Mode 3/A targets in the sweep immediately preceding the Mode C sweep. The characteristics of these patterns shall be as follows.

The diagram illustrates the timing relationships for several video signals. The signals are listed on the left, and their corresponding waveforms are shown on the right. Key timing parameters are indicated by arrows and labels:

- VIDEO:** Shows a single pulse labeled **F1**. The duration of the pulse is marked as **ADJUSTABLE DELAY (1/16 NM INC.)**.
- SINGLE SLASH:** Shows a single pulse with a duration of **0.8μsec**.
- DOUBLE SLASH:** Shows two pulses with a duration of **0.8μsec** between them.
- TRIPLE SLASH (CH1 ONLY):** Shows three pulses with a duration of **0.8μsec** between them.
- BLOOMER:** Shows a single pulse with a duration of **0.8μsec**.
- DOUBLE BLOOMER:** Shows two pulses with a duration of **0.8μsec** between them.
- WIDE BLOOMER:** Shows a single pulse with a duration of **0.8μsec**.
- DOUBLE SLASH BLOOMER:** Shows two pulses with a duration of **0.8μsec** between them.

60.A.3.2.1.6.1 Single slash.- The single slash shall be a pulse, corresponding to the range of the received reply. The range positioning of the Video Reconstitutor/decoder outputs to the display shall be identical for all displays. An adjustment shall be provided by wire-strapping or other similar accessible means, to vary the position of the slash ± 2 nmi in range, independent of the real time adjustment of beacon pretrigger and range counter preset. The pulse width of the single slash shall be 0.8 ± 0.1 microseconds.

60.A.3.2.1.6.2 Double slash.- The double slash shall be the single slash followed by a second slash. The spacing between slashes shall be a basic parameter used in generating all the other patterns on that display. It shall be capable of being adjusted to one of three values as a function of the display's range selection switch to approximate constant spacing on the display regardless of the range selected. Provision shall be made for selection of one of three spacing values. These values shall be 4.14, 8.3, or 11.6 microseconds. Selection of the spacing shall be controlled by three lines from the display. Activation of the selected line shall be by a contact closure. The pulse width of the second slash shall be 0.8 ± 0.1 microseconds.

60.A.3.2.1.6.3 Triple slash.- The triple slash shall be the double slash followed by a third slash. The spacing between slashes shall be a basic parameter used in generating all the other patterns of that display. It shall be capable of being adjusted to one of three values as a function of the display's range selection switch to approximate constant spacing on the display regardless of the range selected. Provision shall be made for selection of one of three spacing values. These values shall be 4.14, 8.3 and 11.6 microseconds. Selection of the spacing shall be controlled by three lines from the display. Activation of the selected line shall be by a contact closure. The pulse width of the third slash shall be 0.8 ± 0.1 microseconds.

60.A.3.2.1.6.4 Bloomer.- The bloomer shall be generated by the filling of the space between the double slash. The pulse width of the bloomer shall follow the double slash spacing as a function of the display's range selection switch.

60.A.3.2.1.6.5 Double bloomer.- The double bloomer shall be the single bloomer followed by a second bloomer. The space between bloomers shall be approximately equal to the width of a bloomer.

60.A.3.2.1.6.6 Wide bloomer.- The wide bloomer shall be generated by the filling in of the space between the double bloomer.

60.A.3.2.1.6.7 Double slash, bloomer.- The double slash bloomer shall be a double slash followed by a bloomer.

60.A.3.2.1.6.8 Bloomer, slash.- The bloomer slash, a combination of an SPI bloomer and the triple slash function, shall be generated by filling of the space between the first and second slash of the triple slash. The pulse width of the bloomer shall follow the spacing of the first and second slash as a function of the display's range selection switch.

60.A.3.2.1.7 Display output interface.- The Video Reconstitutor/Decoder output signals shall have the following characteristics as measured at the output of 300 foot cable terminated in 75 ohms:

Polarity:	Positive
Amplitude:	2.0 to 5.0 volts adjustable
Rise Time:	0.1 microsecond Max
Fall Time:	0.2 microsecond Max
Impedance:	75 \pm 5 ohms
Cable Type:	RG-59A/U or equivalent

This space intentionally unused.

FAA-E-2716
APPENDIX VI-A

-VI-A-12-
(Last page of Appendix VI-A)

This page intentionally unused.

FAA-E-2716
APPENDIX VII

-VII-1-

APPENDIX VII
MODE SELECT BEACON SYSTEM SENSOR
VIDEO DELAY UNIT

APPENDIX VII
MODE SELECT BEACON SYSTEM SENSOR
VIDEO DELAY UNIT

70.1. SCOPE.

70.1.1 Scope.- This appendix specifies a video delay unit capable of delaying primary radar (airport surveillance radar) video outputs sufficiently to bring radar video and reconstituted ATCRBS beacon video from the Mode S sensor/Reconstitutor into registration on the ATC facility displays. In this configuration it is assumed that the Mode S sensor does not have digitized primary radar inputs.

70.2. DEFINITIONS.

(None)

70.3. REQUIREMENTS.

70.3.1 Design requirements.- Unless otherwise specified in this appendix, the design of the video delay unit shall meet all of the hardware and software requirements specified in the body of this document.

70.3.2 Performance requirements.- A block diagram showing signal flow between the Mode S sensor the primary radar, the delay unit, the reconstitutor, and the ATC display facility is shown in Fig. VII-1. This functional diagram is not binding upon the arrangement of the hardware.

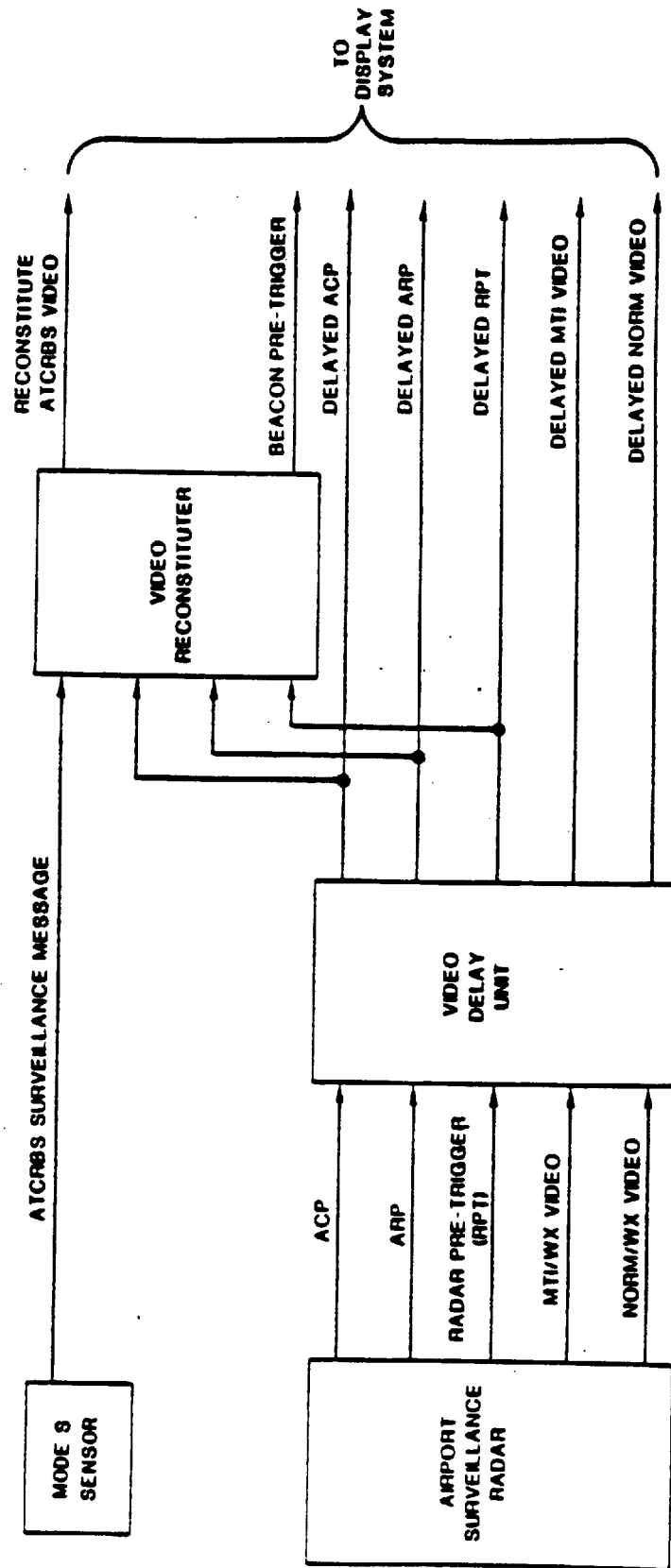


Figure VII-1 Video Delay and Interface Block Diagram

70.3.2.1 Overall operation.- The video delay unit shall delay the ASR primary radar videos, pretrigger, and azimuth inputs by means of digital storage and readout techniques in order to provide registration of these outputs with reconstituted ATCRBS video output. This unit may be an independent unit or it may be combined in the same mechanical package as the Mode S video reconstitutor. ASR videos delayed shall include MTI and Normal, with either containing weather data. Delay shall be selectable from 1.0 ms to 2.0 seconds at 1200 PRP. Restriction of the delay selections to an integer number of radar PRFs is permitted (if implemented the radar pretrigger may be passed through).

70.3.2.2 Video delay unit inputs.-

- (a) ACP and ARP azimuth pulses: The video delay unit shall accept and delay the airport surveillance radar azimuth change pulses (ACP's), and azimuth reference pulses (ARP's).
- (b) Video: The delay unit shall accept and delay the 2 to 4 volt video inputs from the ASR radar. Separate inputs shall be provided for MTI/Wx, and Normal/Wx signals. The delay unit shall also accept the pretrigger associated with these video signals.

70.3.2.3 Video delay unit outputs.- The video delay generator shall provide separate isolated outputs for each of the inputs listed in 70.3.2.2. The output shall be 2 to 4 volts into 91 ohms for video, +5 volts into 91 ohms for the pretrigger and +5 volts into 75 ohms for the ACP and ARP pulses.

70.3.2.4 Video delay unit performance.- The video delay generator shall include the necessary storage and control circuits to provide the following:

- (a) Delay time - 1.0 ms to 2.0 seconds at 1200 pulses per second PRF
- (b) Maximum range - 60 nmi
- (c) Range accuracy - 1/16 NMI
- (d) Digital storage resolution:
 - (1) Video signals - 1/16 nmi
 - (2) Pretrigger timing resolution - the sweep to sweep delay from radar pretrigger to synthesized zero time shall be within 38.6 ns.
 - (3) ACP/ARP timing resolution - Delayed ACP/ARP pulses shall be located within +/-20 us relative to pretrigger prior to being delayed.

(e) Video levels:

(1)	MTI Video	3 bits	8 levels
(2)	Normal Video	3 bits	8 levels
(3)	Weather contour*		
(4)	Pretrigger	1 bit	1 level
(5)	ACP pulses	1 bit	1 level
(6)	ARP pulse	1 bit	1 level

* Combined in (1) or (2) above.

70.3.2.5 Synchronization of reconstitutor.- The delayed ACP pulses, ARP pulses and pretrigger shall be available for use by the video reconstitutor to provide registration between the video output of the delay unit and video output of the reconstitutor.

70.3.3 Interfaces.

70.3.3.1 Primary radar to video delay unit.- The video delay generator shall be capable of accepting video, pretrigger, and azimuth inputs from an ASR radar. This shall include MTI/Wx, Normal/Wx, ACP, ARP, and pretrigger.

70.3.3.2 Video delay unit to video reconstitutor.- The video delay unit shall provide isolated, delayed, outputs of ACP, ARP and the radar pretrigger for use by the video reconstitutor.

70.3.3.3 Video delay unit to ATC facility.- The video delay generator shall provide isolated delayed outputs of the video input data of 70.3.3.1 for use by an ATC facility.

This space intentionally unused.

FAA-E-2716
APPENDIX VII

-VII-6-
(last page of Appendix VII)

This page intentionally unused.

APPENDIX VIII

MODE SELECT BEACON SYSTEM SENSOR

CALIBRATION PERFORMANCE MONITOR EQUIPMENT (CPME)

APPENDIX VIII

MODE SELECT BEACON SYSTEM SENSOR

CALIBRATION PERFORMANCE MONITOR EQUIPMENT (CPME)

80.1. SCOPE.

80.1.1 Scope.- This appendix specifies the design, fabrication, quality assurance, and preparation for delivery of a Mode S sensor calibration performance monitor equipment (CPME). The CPME is a Mode S test transponder, two or more of which are to be installed at fixed sites visible to a Mode S sensor and used for calibration and test of the sensor.

80.2. DEFINITIONS.- All ATCRBS transponder terms and definitions as used in applicable ATCRBS documents and in the Mode S National Standard apply to the Mode S sensor CPME's. The Mode S-Only All-Call interrogation format shall be as defined in Table 3.4.1-1 of this specification.

80.3. REQUIREMENTS.

80.3.1 Equipment and services to be provided.- The deliverable items shall include the CPME assembly with power supply, its antenna, and necessary antenna and power cabling.

80.3.2 Configuration and interfaces of equipment.

80.3.2.1 Transponder.- The CPME is a remote Mode S test transponder. Conventional ATCRBS transponder Mode 3/A and C capability, plus military Mode 2 capability, plus full Mode S capability shall be provided. The Mode S modes handled by the CPME shall include All-Call and surveillance uplink and downlink transmissions, single-segment uplink (Comm-A), and downlink (Comm-B) communications transmissions, and extended length uplink (Comm-C) and downlink (Comm-D) communications transactions.

80.3.2.2 Interfaces and display.- The CPME shall include the functional capabilities of an interface for standard messages (SM) for transferring to and reading from an interface test circuit the contents (exclusive of the address/parity field) of Mode S uplink (Comm-A) and downlink (Comm-B) transmissions respectively. It shall also include the functional capabilities

of an extended-length-message (ELM) interface for transferring to and reading from an ELM interface test circuit the message contents of Mode S extended-length uplink (Comm-C) and downlink (Comm-D) transmissions, respectively. The CPME shall transmit altitude reports from an internally simulated pressure-altitude encoder (digitizer).

The CPME shall not include interfaces for connection to external SM, ELM, or altitude encoding devices. Built-in interface test capability shall be provided whose performance shall appear to the sensor to be functionally equivalent to that of ordinary Mode S transponder interfaces. However, identifiable interface hardware of the type required for operational Mode S transponders is not required.

80.3.3 Mode S CPME technical characteristics.

80.3.3.1 Reply conditions.

80.3.3.1.1 ATCRBS reply condition.- The CPME shall reply to standard military Mode 2, ATCRBS Mode 3/A, and Mode C interrogations under the conditions prescribed in FAA Order 1010.51A, except during recovery following a Mode S reply. The CPME shall not reply to ATCRBS interrogations under the conditions prescribed in FAA Order 1010.51A for no reply.

80.3.3.1.2 ATCRBS/Mode S All-Call reply conditions.- The CPME shall reply to an ATCRBS/Mode S All-Call (Mode A or Mode C) interrogation, or an ATCRBS-only All-Call interrogation as specified in the Mode S National Standard, except during recovery following a Mode S or ATCRBS reply, or when the conditions of 80.3.3.1.7 specify otherwise. The CPME shall not reply (with either an All-Call, an ATCRBS, or Mode S reply) in response to an ATCRBS/Mode S All-Call interrogation when the interrogation contains a P2 pulse which satisfies the requirements for ATCRBS suppression. The CPME shall not produce a Mode S All-Call reply in response to a CW transmission or a single pulse of long duration whose received amplitude variations do not approximate an All-Call interrogation. The CPME shall not produce a Mode S All-Call reply in response to a P1-P3 pair alone. In order to elicit an All-Call reply, the P1-P3 transmission shall be followed by a distinct P4 pulse, as specified in the Mode S National Standard.

80.3.3.1.3 Mode S reply conditions.- The CPME shall reply (with probability specified below) to valid Mode S interrogations (Mode S-only All-Call, Surveillance, Comm-A or Comm-C) as described in the Mode S National Standard, which are correctly addressed and within specified limits of received signal amplitude, except when the CPME is in a lockout condition or a recovery state from a prior Mode S or ATCRBS reply. The CPME shall not reply to a Mode S interrogation whenever any one or combination of the following conditions occur:

- (a) The decoded bits corresponding to the address/parity field contain other than the CPME's unique discrete address, or, in the case of a Mode S-only All-Call, if the decoded parity field is not consistent with a Mode S-only All-Call.
- (b) A lockout condition for the ATCRBS/Mode S or Mode S-only All-Call (with or without site addressing) inhibits reply.
- (c) The interrogation content indicates no reply is requested.
- (d) A Mode S sidelobe-suppression (SLS) condition inhibits replies.
- (e) A stochastic Mode S-only All-Call is received and a comparison of the commanded reply probability compared to the random process outcome indicates that no reply should be generated.

The CPME shall not reply to a CW transmission or single pulse of long duration whose received amplitude variations do not approximate a Mode S interrogation.

80.3.3.1.4 Mode S SLS.- The CPME shall not reply with greater than 5 per cent probability to correctly-addressed Mode S uplink transmissions in which a Mode S SLS pulse (P₅), as specified in the Mode S National Standard is received with amplitude exceeding that of the data block by 3 dB or more. The CPME shall reply with greater than 95 per cent probability to valid Mode S uplink transmissions if the received amplitude of the P₅ pulse is 6 dB or more below that of the data block. These conditions apply over the entire specified reply range of the transponder.

80.3.3.1.5 Mode S sensitivity and dynamic range.- When all other reply conditions are satisfied, the sensitivity of the CPME shall be such that replies are generated to at least 95 per cent of the Mode S surveillance, Mode S-only All-Call or Mode S Comm-A uplink transmissions, when, in the absence of interference, the amplitude of the signal received at the CPME RF port exceeds a triggering level which is manually variable (continuously or in 1-dB steps) over a range of -30 dBm to 0 dBm. The setting of the triggering level shall be accurate to within ± 2 dB for all settings. The receiver dynamic range shall exceed 40 dB for all triggering level settings. Under the same set of conditions, the reply probability shall be at least 99 per cent for all received signal levels from 3 to 17 dB above the selected triggering level.

80.3.3.1.6 Interference rejection.- For all received signal levels from 3 to 20 dB above the selected triggering level and when all other reply conditions are satisfied, the CPME shall reply to at least 95 per cent of all Mode S uplink transmissions in the presence of a standard interfering pulse (defined as a single 0.8 μ s wide pulse with carrier frequency of 1030 MHz \pm 0.1 MHz,

incoherent with the Mode S signal carrier frequency and overlapping any part of the Mode S transmission (except that its leading edge shall occur no earlier than 0.5 μ s following the sync phase reversal), with signal-to-interference ratio (defined as the ratio of the peak amplitude of the Mode S signal to the peak amplitude of the interfering pulse) of 6 dB or more. Also, the CPME shall reply to at least 50 per cent of the Mode S uplink transmissions when the signal-to-interference ratio is 3 dB or more.

80.3.3.1.6.1 Rejection of low-level asynchronous interference.- For all received signal levels from 6 to 17 dB above the selected triggering level and when all other reply conditions are satisfied, the CPME shall reply correctly with at least 90% probability to Mode S uplink transmissions in the presence of asynchronous interference consisting of single 0.8-microseconds-wide RF pulses with carrier frequency of 1030 MHz \pm 0.1 MHz generated at all repetition rates up to 10,000 Hz when the signal-to-interference ratio is 12 dB or more. When, under these same conditions, the CPME is locked out to ATCRBS/Mode S All-Call, interrogations, the Mode S reply probability shall exceed 95%.

80.3.3.1.7 ATCRBS Reply Conditions.- The PC field of a Mode S interrogation shall be used to control the CPME response to ATCRBS/Mode S and ATCRBS-only All-Call interrogations. The CPME shall retain the state of the PC field for use in determining the correct response to these interrogations as specified in Table VIII-1. The PC field state shall be updated each time the CPME replies to a discrete Mode S interrogation.

80.3.3.1.8 Dead time.- After reception of a valid Mode S or ATCRBS interrogation, the CPME shall process no other interrogation until completion of the corresponding reply. After replying to an ATCRBS or Mode S interrogation, the CPME shall be capable of replying to a following ATCRBS or Mode S interrogation whose P₁ pulse is received at least 125 μ s following the transmission of the last pulse of the reply, provided the transmitter duty cycle limits of 80.3.3.4.2 are not violated.

Under the provisions of 80.3.3.1.5, and in the absence of a valid interrogation, the random triggering rate of Mode S replies shall not be greater than one reply per 5 seconds averaged over a period of at least 30 seconds, and the random triggering rate of false data transfers over the interface for standard messages (see FAA-RD-74-64) shall not exceed one per hour.

80.3.3.2 Lockout Control.- Replies to ATCRBS/Mode S All-Call interrogations, and site addressed Mode S only All-Call interrogations shall be independently locked out upon receipt of an interrogation with the appropriate code bits set, as described in the Mode S National Standard.

80.3.3.2.1 Squitter suppression.- The CPME shall not produce spontaneous replies (squitters) for passive acquisition as described in the Mode S National Standard.

TABLE VIII-1
CPME REPLIES TO ALL-CALL INTERROGATIONS

<u>Mode S</u> <u>Lockout</u> <u>State (1)</u> 1=Locked Out	<u>PC State</u> 1 = PC = 7 0 = PC ≠ 7	<u>CPME RESPONSE TO</u>			
		<u>ATCRBS/Mode S</u> <u>All-Call</u>	<u>ATCRBS-Only</u> <u>All-Call</u>	<u>Mode S Only</u> <u>All-Call</u>	<u>Military Mode S</u> <u>Interrogation</u>
0	0	Mode S All-Call Reply	None	Mode S All-Call Reply	Military Mode S Reply
0	1	Mode S All-Call Reply	None	Mode S All-Call Reply	Military Mode S Reply
1	0	ATCRBS Reply (2)	ATCRBS Reply (2)	None (3)	Military Mode S Reply
1	1	None	None	None (3)	Military Mode S Reply

- (1) Lockout state to this interrogation. Address of interrogator and lockout state must match if site address Mode S-only All-Call is used.
- (2) Mode A or C depending on P₁ - P₃ spacing.
- (3) Mode S All-Call reply if lockout override is used.

80.3.3.2.2 Mode S lockout.- ATCRBS/Mode S All-Call interrogations and Mode S-only All-Call interrogations (with or without site addressing) shall be selectively locked out as described in the Mode S National Standard.

80.3.3.2.3 Mode S lockout time-out.- A time-out circuit shall be used to ensure that lockout conditions do not remain in effect after contact with a Mode S sensor has been lost. Discrete address interrogations which activate the time-out circuit shall initiate lockout as specified in the Mode S National Standard. The time-out circuit shall be activated or overridden as specified in the Mode S National Standard, except that a transition from a locked out state to an unlocked state shall occur immediately upon receipt of an interrogation that does not contain a lockout command.

80.3.3.2.4 Mode S contact time-out durations.- The standard time-out circuit shall remain active for a period of T_{SC} seconds following each reply to a discrete address interrogation from a standard Mode S sensor. T_{SC} shall be independently adjustable over the range of 5 to 25 seconds with a nominal value of 18 seconds and an accuracy of ± 12.5 per cent at any setting. The means for adjusting T_{SC} need not be accessible on the control panel of the CPME.

80.3.3.3 Recovery times.

80.3.3.3.1 ATCRBS recovery times.- All CPME recovery times related to ATCRBS interrogations and replies shall be as prescribed in DOT 1010.51A.

80.3.3.3.2 Mode S recovery times.- All CPME recovery times related to Mode S interrogations and replies shall be as prescribed in the Mode S National Standard.

80.3.3.4 Reply rate limiting.

80.3.3.4.1 ATCRBS replies.- ATCRBS reply rate limiting shall operate in accordance with the provisions of paragraphs 2.7.10.1 and 2.7.10.3 of DOT 1010.51A.

80.3.3.4.2 Mode S replies.- Mode S reply rate limiting shall operate in accordance with the provisions of the Mode S National Standard.

80.3.3.5 Reply delay and jitter.- The reply delay for replies to ATCRBS and Mode S interrogations shall be in accordance with the provisions of DOT 1010.51A and the Mode S National Standard respectively, except that provision shall be made to add additional increments of delay from 0 to 2048 μ sec in steps of 16 μ sec over that specified for ATCRBS and Mode S replies. A switch shall be provided on the front panel for setting the reply delay. The selected CPME time delay shall meet the requirements of FAA Order 1010.51A and the Mode S National Standard for delay accuracy. When an additional delay is selected, the CPME shall be inactive for the selected delay time (except for asynchronous timers, e.g., lockout timers) and shall not decode further interrogations until the delayed response has been given. In no event shall the CPME reply jitter exceed 35 nsec RMS.

80.3.3.6 Transmitter characteristics.

80.3.3.6.1 Power output.- The CPME shall operate in one of two modes: low power (+15 dBm maximum output at RF port) and high power (+55 dBm output at RF port). The high power/low power select switch shall be located on the CPME front panel.

80.3.3.6.1.1 Low power mode.- When using the internal transmitter source, or an external transmitter source (80.3.5.4) set at a fixed level of +10 dBm, the CPME power output in low power mode, measured at the CPME RF port shall be variable (continuously or in 1-dB steps) over a range of -47 dBm to +15 dBm. The power setting shall be accurate within ± 2.0 dB for all settings and for all pulses of all replies. Note: when equipped with a single horn antenna, a CPME RF output of +15 dBm should be sufficient to produce a -51 dBm signal at the RF port of a sensor 0.3 nmi away (see 80.3.3.6.1.3.4).

80.3.3.6.1.2 High power mode.- When using the internal transmitter source, or an external transmitter source (80.3.5.4) set at a fixed level of +10 dBm, the CPME power output in high power mode, measured at the CPME RF port shall be variable (continuously or in 1-dB steps) over a range of +10 dBm to +55 dBm. The power setting shall be accurate to within ± 2.0 dB for all settings and for all pulse of all replies. Note: when equipped with a single horn antenna, a CPME RF output of +45 dBm should be sufficient to produce a -57.5 dBm signal at the RF port of a sensor 20 miles away (see 80.3.3.6.1.3.4).

80.3.3.6.1.3 Notes on CPME-to-sensor radio link calculations.- To determine the signal levels produced at a sensor RF port by a CPME, the following equations are used:

$$P_0 + G_1 - L + G_2 = P_i$$

where

P_0 is the power output from the CPME RF port

G_1 is the gain of the CPME antenna system including cabling

L is the free space loss

G_2 is the gain of the sensor's antenna system including cabling and rotary joint

P_i is the resulting power at the sensor's RF port.

80.3.3.6.1.3.1 CPME antenna system gain.- The CPME uses a 14 dB gain horn antenna (80.3.5.2) and assumes a loss of 6 dB in the cable connecting the antenna to the CPME RF port (80.3.5.3); this results in $G_1 = +8$ dB.

80.3.3.6.1.3.2 Free space loss.-

$L = 98.5 + 20 \log (\text{Range})$, where

Range is the distance from the CPME to the sensor in nautical miles.

80.3.3.6.1.3.3 Sensor antenna system.- For purposes of calculation, a sensor with a +21 dB gain antenna, 5 dB elevation loss due to antenna beam shaping, and 2 dB cable loss has been assumed, giving $G_2 = +14$ dB.

80.3.3.6.1.3.4 Graph.- The CPME-to-sensor link power budget is summarized in Fig. VIII-1. For example, if $P_0 = +15$ dBm for the CPME, a level of -51 dBm is produced at the RF input port of a sensor which is 0.3 miles away. Similarly, $P_0 = +50$ dBm should give $P_1 = -52.5$ dBm for a range of 20 nmi. Note that since reciprocity holds, the same graph can be used to determine the signal level produced by a sensor at the CPME RF port. For example, if $P_0 = 800$ watts = +59 dBm is the sensor output, a level of -43.5 dBm is produced at the RF port of a CPME located 20 nmi away.

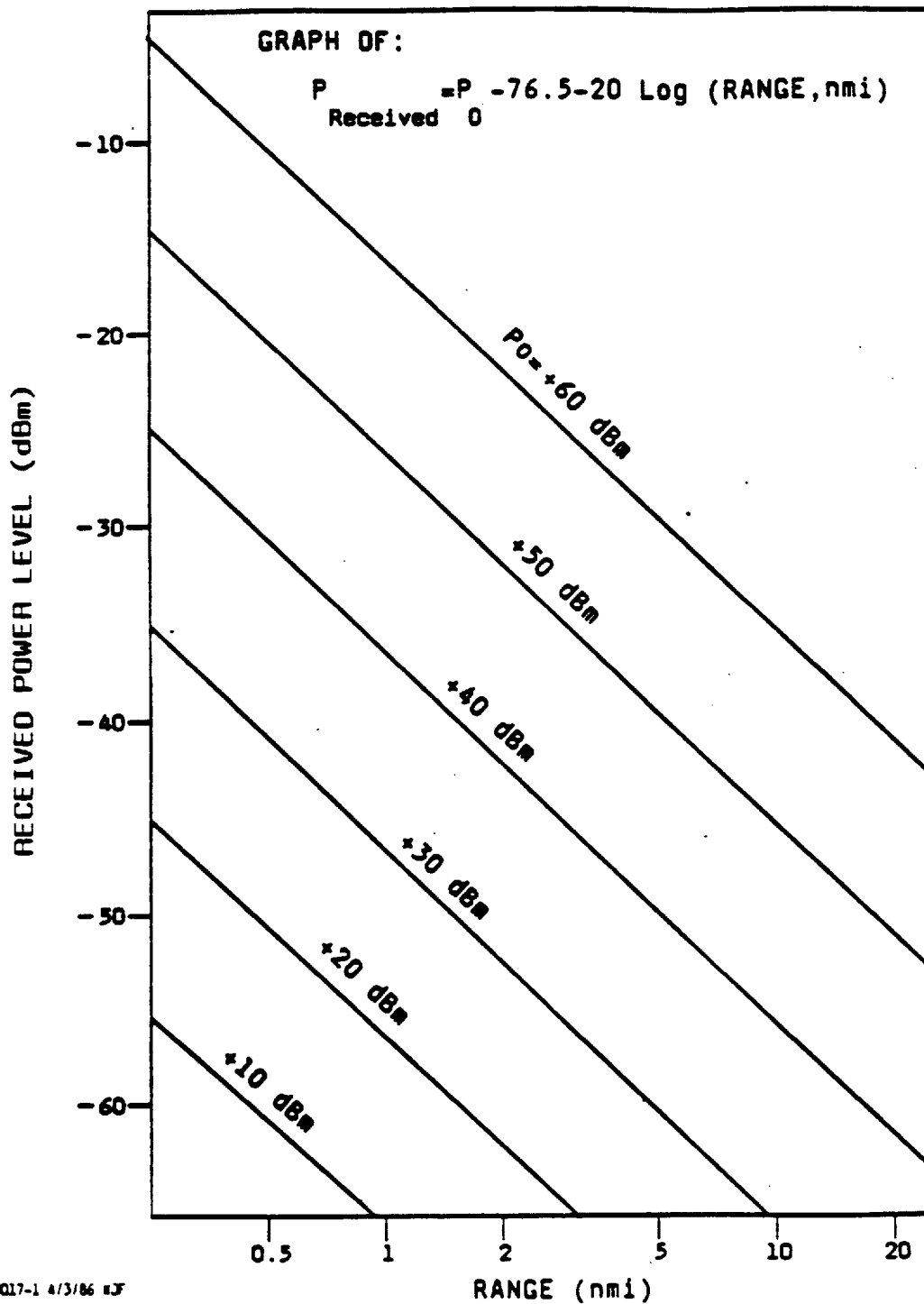
80.3.3.6.2 Droop.- The pulse amplitude variation of one pulse with respect to any other pulse in an ATCRBS or Mode S reply shall be in accordance with the provisions of FAA Order 1010.51A and the Mode S National Standard, respectively.

80.3.3.6.3 Frequency.- The carrier frequency of all reply transmissions shall be 1090 ± 0.1 MHz, except when the external source is selected.

80.3.3.6.4 Pulse shape and timing.- The pulse shape and timing of all ATCRBS and Mode S replies shall be in accordance with the provisions of FAA Order 1010.51A and the Mode S National Standard, respectively.

80.3.3.6.5 Peak reply rate.- The CPME shall be capable of transmitting Mode S replies in accordance with the provision of the Mode S National Standard for a transponder equipped with 16-segment Comm-D capability.

80.3.3.6.6 Modulator CW inhibitor.- The CPME shall sense for continuous transmission of the 1090 MHz carrier (due, for example, to modulator failure). Built-in circuitry shall automatically disable the CPME 1090 MHz source within 100 ms of sensing the presence of this failure condition.



PCA6/ASQ17-1 4/3/86 NJ

FIGURE VIII-1. POWER LEVEL RECEIVED FROM CPME.

80.3.3.7 Reply formats.

80.3.3.7.1 ATCRBS reply formats.- The ATCRBS reply codes shall be in accordance with the provisions of FAA Order 1010.51A, except the CPME shall not be required to transmit the ATCRBS special position identification pulse.

80.3.3.7.2 Mode S reply formats.- The Mode S reply formats shall be in accordance with the Mode S National Standard. The CPME shall be capable of surveillance, All-Call, Comm-B, C, and D reply types as defined therein.

80.3.3.7.2.1 Basic capability code.- The CPME shall respond to All-Call interrogations with a 3-bit capability code in accordance with the protocol described in the Mode S National Standard. A code shall be entered to indicate the presence of extended capability in accordance with the Mode S National Standard.

80.3.3.7.2.2 Extended capability report.- In response to a correctly addressed interrogation with RR=17, the CPME shall transmit a Comm-B reply indicating full ELM capability in accordance with the provisions of the Mode S National standard.

80.3.3.7.2.3 CPME status.- In response to a correctly addressed interrogation with RR=17. The CPME shall transmit a Comm-B reply giving CPME status in the ACS subfield of the extended capability report. Provision shall be made for at least the following conditions:

- Bit 45: oscillator out of phase-lock.
- Bit 46: power fail.
- Bit 47: inside of enclosure under-temperature.
- Bit 48: inside of enclosure over-temperature.
- Bit 49: miscellaneous fault conditions.
- Bit 50: PC=7 state.
- Bit 51: Mode S All-Call lockout state.

The states reported by status bits 45-51 are the states in effect after the reply has been completed. All "fault bits" (45-49 above) shall be OR'ed together and this bit shall be transmitted as the SPI condition (PS field of the surveillance or Comm-B reply).

80.3.3.7.2.4 Call sign transmission.- In response to a correctly addressed interrogation with RR=18, the CPME shall transmit a Comm-B reply with a dummy call sign contained in the MB field in accordance with the following.

80.3.3.7.2.5 Call sign format.- The CPME call sign shall consist of 48 binary bits set by a coded connector plugged into the CPME front panel. The call sign shall be transmitted in bit positions 41 through 88 of the Comm-B data

field inclusive. The use of a plug-in connector configured with 48 jumper wires, the removal of any one of which sets the corresponding bit in the call sign field, represents one acceptable implementation.

80.3.3.7.2.6 Flight status.- The flight status field in downlink surveillance and Comm-B transmissions shall always be transmitted as code one by the CPME except for the SPI condition of 80.3.3.7.2.3.

80.3.4 Interface test circuits.- Each CPME shall be equipped with test circuits capable of testing the functional requirements of the interface for standard messages and the ELM interface. The test circuits specified below may be implemented as one or more distinct logical modules, or they may be integrated into the overall CPME logical function. For clarity, the following specification postulates the existence of identifiable internal interfaces.

80.3.4.1 Standard message test (SMT).- MA messages received by the CPME shall be routed to this circuit. The receipt of an interrogation with an MA text shall cause this circuit to input a "message waiting" code to the internal standard message interface for inclusion in subsequent CPME replies. When the sensor data processing system receives the reply from the CPME with the "B bit set" code, it will respond with a command (RR=16) to transmit the message which is waiting. Receipt of RR=16 shall cause the SMT circuit to supply to the internal SM interface an MB message text which is identical to the text of the MA message which initiated the sequence. After this Comm-B message has been received by the sensor, the transaction is closed out by the transmission of cancel B code to the CPME in accordance with the Mode S National Standard for non-selective or multisite Comm-B delivery.

80.3.4.2 Extended length message test (ELMT).- The CPME shall include ELM transponder circuitry capable of handling 16 ELM segments in either direction according to the non-selective or multisite protocol defined in the Mode S National Standard. Upon completion of an uplink ELM transaction, the uplink message shall be transferred to the ELMT circuit. Upon completion of this data transfer, the ELMT shall automatically use an interface signaling procedure to initiate a downlink transfer of a message containing precisely the same text as the uplink ELM which initiated the sequence. The air-to-ground transmission of the ELM shall then be completed by the ELM transponder circuitry in the CPME according to the protocol defined in the Mode S National Standard.

80.3.4.3 Altimeter input simulator.- This circuit shall conform to the code requirements of a pressure-altitude encoder (digitizer). It shall provide for the transmission of a simulated 12-bit altitude code set by a coded connector plugged into the CPME front panel. The use of a plug-in connector configured with 12 jumper wires, the removal of any one of which sets the corresponding bit in the altitude report, represents one acceptable implementation.

80.3.5 Interface and mechanical specifications.

80.3.5.1 Controls and indicators.

80.3.5.1.1 Controls required.- The following controls shall be provided:

- (a) Master control: OFF-STBY-ON switch.
- (b) Mode A code Selector: A set of four octal switches used to select the 4096 Mode A code. The code selector shall not control the Alert (A) bit as specified in the Mode S National Standard.
- (c) Mode 2 code Selector: A receptacle for a coded plug used to select the 12-bit Mode-2 code.
- (d) Altitude selector: A receptacle for a coded plug used to select a simulated altitude code (80.3.4.3).
- (e) Address Selector: A receptacle for a coded plug used to select the 24-bit transponder address.
- (f) CPME call sign Selector: A receptacle for a coded plug used to select the 48-bit CPME call sign code (80.3.3.7.2.5).
- (g) Output power: Controls for varying the transmitter output power (80.3.3.6).
- (h) Triggering level: A control for varying the receiver triggering level from -50 dBm to 0 dBm (80.3.3.1.5).
- (i) Turnaround delay: 0-2048 μ s (16 μ s steps). Selects additional turnaround time delay.
- (j) Transmitter source: Internal-external switch. Selects source for RF carrier of transmitted signal (80.3.5.4).

80.3.5.1.2 Indicators required.- The following indicators shall be provided:

- (a) Mode S indicator - A light, flag, or other suitable indicator which indicates the current status of the standard time-out circuit (80.3.3.2.3). The Mode S indicator shall be activated upon replying to a properly addressed Mode S interrogation, and shall remain activated for an interval T_{SC} following the interrogation.
- (b) ATCRBS indicator - A light, flag, or other suitable indicator which momentarily flashes when a reply to an ATCRBS interrogation is transmitted.

80.3.5.2 Antenna.- The CPME shall be provided with a horn antenna having a gain of 14 ± 1.0 dB at 1030 and 1090 MHz. (A Scientific-Atlanta, Inc., standard gain horn, Model 12-0.9, or equivalent is acceptable). A low-loss, weather-proof radome and suitable mounting hardware for the horn shall also be provided.

80.3.5.3 Antenna cable.- A coaxial cable that interfaces with the antenna and the CPME shall be supplied. This cable shall satisfy the following specifications:

Length	150 feet, min
Impedance	50 Ohm, nominal
Loss	0.04 dB/foot max from 1030 to 1090 MHz
Diameter (outside)	0.625 inches, max

(Andrew Corp., type FHJ4-50B (RG-366/U) or equivalent is acceptable).

80.3.5.4 Provision for external signal source.- A port shall be provided for the insertion of an external CW signal to be used for test purposes in place of the internally generated transmitter carrier. The frequency of the external signal will be varied as part of the sensor monopulse accuracy tests specified in 4.3.3.5.2 of the body of this specification. (The frequency of the external signal will be varied between 1087 and 1093 MHz. The power level of the external source shall be set at a fixed value of +10 dBm. The CPME peak RF power output can then be varied from +55 dBm to +10 dBm in the high power mode and from +15 dBm to -47 dBm in the low power mode).

80.3.5.5 Connectors and adaptors.- Sufficient cable connectors and adaptors shall be provided for connecting the CPME to the horn antenna via the antenna cable.

80.3.5.6 Enclosure.- The CPME shall be housed in the lockable enclosure designed for stand-alone installation in an outdoor environment, and shall be consistent with possible installation on a concrete or asphalt pad at ground level, or inside or on a building. The CPME control panel shall be accessible by opening the enclosure. Suitable mounting hardware and a lock shall also be provided.

80.3.5.7 Size and weight.- No restrictions are placed on size and weight other than that they be consistent with the intended use of the equipment. Sufficient front panel area and internal volume shall be reserved to accommodate a 20 per cent future expansion in the number of control and electronic components.

80.3.5.8 Power.- The design center value for primary power shall be 120 VAC, 60 Hz, single phase (FAA-G-2100, para. 3.3.2.5). Suitable power cabling and connectors shall be provided.

80.3.5.8.1 Battery supply.-

(a) The CPME shall operate from rechargeable batteries. The battery supply shall permit operation for not less than two (2) hours under the ambient conditions of Environment II, FAA-G-2100, without primary power applied. Loss of AC power shall cause no interruption of CPME operations.

(b) Each supplied battery shall be provided with an associated container. The container shall be fabricated from fiberglass or other suitable material which is not subject to corrosion from the battery acid or fumes and shall have a removeable cover to provide access to the batteries. The contractor shall provide and install all necessary wiring for interconnecting the battery and the CPME and power supply. The battery container and power supply shall be protected to prevent entry of rain, snow, and insects. Batteries shall be vented to the outside of buildings or structures.

(c) The supply shall provide sufficient power to operate the CPME and simultaneously restore the battery supply to full charge from a fifty (50) percent discharged condition within 36 hours. The equipment shall meet all specifications with or without the battery supply installed. When primary power is applied, the charge state of the battery shall in no way cause harm to, or affect the operation of, the CPME.

80.3.5.9 Environmental service conditions.- The enclosed CPME shall meet or exceed the requirements of Environment III of FAA-G-2100, table II.

80.3.5.10 Maintainability.- The CPME shall be constructed in a manner to facilitate maintenance and repair. Plug-in circuit cards and modularization to reduce the mean-time-to-repair shall be used. The construction shall permit replacement of any component by a skilled technician in less than four hours, with the exception of connectors or transmitter components.

80.3.5.11 Reliability.- The CPME shall be constructed of solid state components (tubes are not permitted), and shall be designed for continuous-duty unattended service. The CPME shall be included within the sensor reliability requirement specified in 3.7.5 and 3.9.2.1 of the main body of this specification. High availability of the CPME shall be achieved by a combination of original equipment selection and design for reliability, coupled with preventive maintenance procedures to isolate and either repair or replace circuits prior to failure.

Operating continuously, the CPME shall meet the following:

- (a) Preventive maintenance (test, adjust, repair, replace, etc.) shall be required no more frequently than once every 91 days.

- (b) The preventive maintenance shall require no more than 30 minutes if no repairs or replacements are needed. If repairs or replacements are required, a total down time of up to one hour is acceptable. The CPME may be shut down for the total time, if necessary.
- (d) The CPME shall recover its full operational capability automatically within one minute following power restoration after an external power interrupt. No damage shall occur to the CPME as a result of power failure.

80.3.5.12 Radio frequency shielding.- In service, the equipment will be operated in the proximity of high power radar equipment from which high frequency energy will be radiated. Provisions shall be made in the equipment for proper operation under such conditions.

This space intentionally unused.

FAA-E-2716
APPENDIX IX

-IX-1-

APPENDIX IX

MODE SELECT BEACON SYSTEM SENSOR

AIRCRAFT REPLY AND INTERFERENCE ENVIRONMENT SIMULATOR (ARIES)

APPENDIX LX

MODE SELECT BEACON SYSTEM SENSOR

AIRCRAFT REPLY AND INTERFERENCE ENVIRONMENT SIMULATOR (ARIES)

90.1. SCOPE.

90.1.1 Scope.- The Aircraft Reply and Interference Environment Simulator (ARIES) specified herein is an automatic test system used to subject Mode S sensors to simulated beacon-equipped aircraft, primary radar, and fruit loads. ARIES is necessary to establish sensor performance during sensor acceptance and installation tests. Computer controlled, and coupled to the sensor via RF connections, ARIES generates pseudo-random fruit replies, Mode S and ATCRBS targets, each with variable range, azimuth and message content, and digitized primary radar targets.

90.2. DEFINITIONS.- A prototype of this system is described in FAA-RD-78-96.

90.3. Requirements.

90.3.1 General.- The purpose of the Aircraft Reply and Interference Environment Simulator (ARIES) is to test Mode S sensors under heavy load. ARIES shall be designed to simulate, at RF, a high density radar beacon environment, and high rates of interfering ATCRBS and Mode S replies ("fruit"). It shall also generate large numbers of primary radar reports such as would be received by a Mode S sensor from a collocated radar operating in a dense traffic environment. The aircraft positions and parameters to be

simulated as well as fruit and radar parameters shall be read from a traffic model provided on magnetic tape. System operation shall be controlled by an operator through appropriate I/O devices. During simulations ARIES shall record data on magnetic tape to aid in ARIES and sensor debugging and in sensor performance analysis.

It shall be possible to connect up to three ARIES units together in a network, for the purpose of testing Mode S sensors operating in the ground netted mode. It shall be possible for a simulated aircraft to be visible at more than one site in this mode, and ARIES shall coordinate the transponder behavior among all sites.

In order to minimize downtime due to simulator failure, and also to assure proper ARIES operation before and after simulation tests, extensive self testing capabilities shall be provided.

A diagram of the major components of an ARIES system is shown in fig. IX-1.

90.3.1.1 Traffic capacity.- ARIES shall be capable of supporting as specified herein any simulated beacon or primary radar environment within the capacity of the Mode S sensor, as specified in section 3.3.2.5 of the main body of this specification. ARIES shall support these environments for 250, 400, and 700 aircraft capacity sensors with either single or dual (back-to-back) antennas.

90.3.2 Interfaces.

90.3.2.1 Interfaces to the Mode S Sensor.

90.3.2.1.1 Interrogation Interfaces.- Interrogations shall be received from the sensor at 1030 MHz via the sensor's ARIES interface as specified in section 3.5.6 of the main body of this document. Provision shall be made for connecting to interrogation signals from both the front and back antenna channels of a sensor with a back-to-back antenna.

90.3.2.1.2 Reply interfaces.- Simulated transponder replies and fruit replies shall be passed to the sensor at 1090 MHz. Signals shall be provided for the I, A, and Q antenna channels, and shall connect to the sensor's ARIES reply interfaces specified in 3.5.6 of the main body of this document. Provision shall be made for generating two such sets of signals, one for the front antenna and one for the back antenna channel of sensors with a back-to-back antenna. Replies may be directed to both antennas simultaneously or may be directed only to the antenna face which generated the interrogation.

90.3.2.1.3 Azimuth interface.- The azimuth interface shall be capable of operating in either of two modes selectable by the operator. In the azimuth repeater mode, ARIES shall receive azimuth change pulses (ACP's) and azimuth

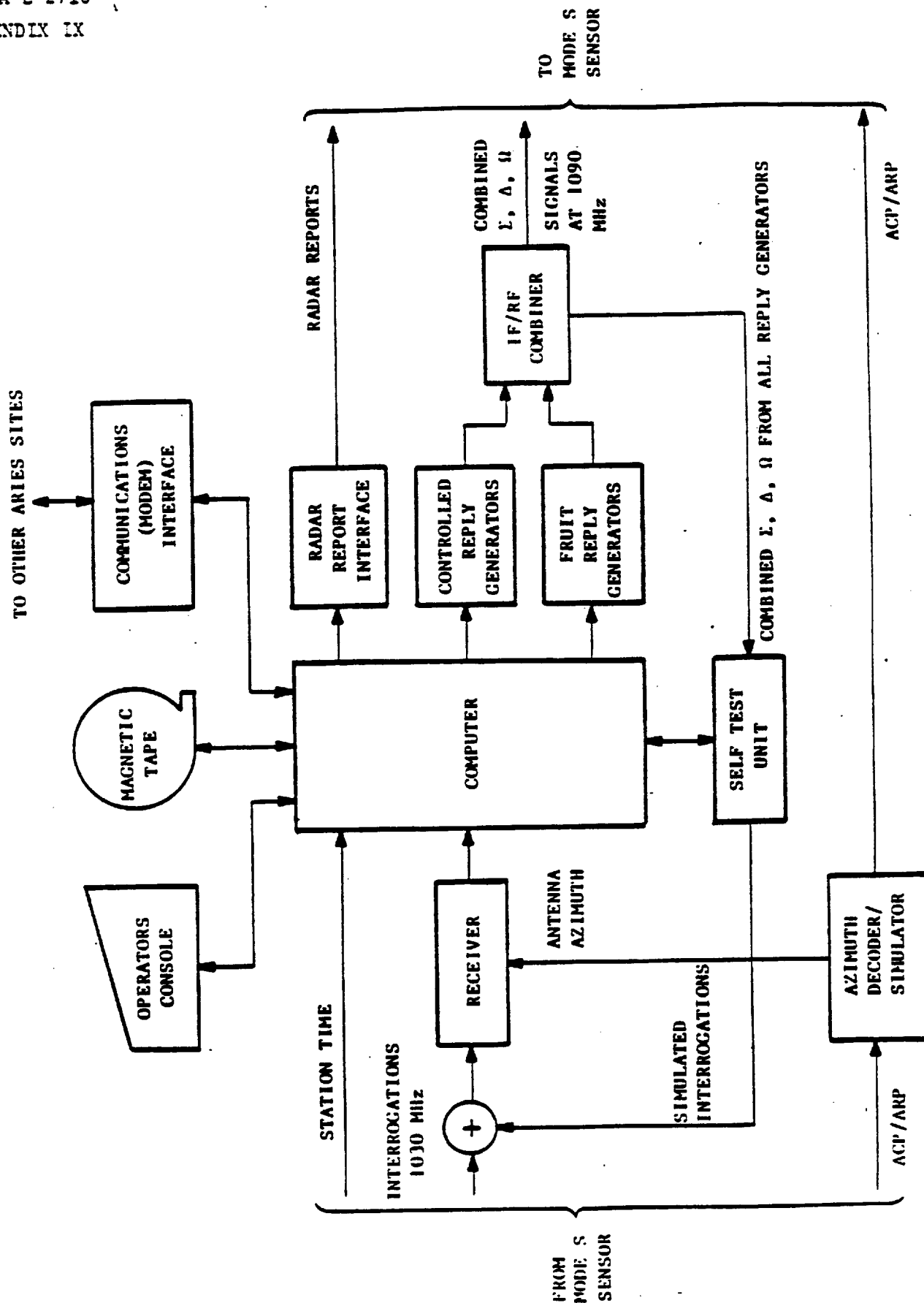


FIGURE IX-1 ARIFS SYSTEM

reference pulses (ARP's) from the Mode S sensor's antenna system. These signals shall then be passed from ARIES to the Mode S sensor's azimuth interface.

In the azimuth simulation mode, ARIES shall ignore the ACP and ARP signals from the sensor's antenna and shall generate these signals itself, again passing these signals to the Mode S sensor's azimuth interface. These signals shall be identical to those which would be generated by an antenna rotating at a specified constant rotation rate. The simulated rotation period shall be adjustable over the range 3.5 to 15.0 seconds in steps of no more than 0.1 second.

The azimuth interface circuitry shall produce a 14 bit parallel azimuth word from the ACP and ARP signals for the use of the rest of the ARIES system. A north correction circuit shall be provided, with the amount of the correction adjustable over the full azimuth range in steps of 1 Au.

90.3.2.1.4 Radar report interface.- ARIES shall be capable of transferring simulated radar data to any of the Mode S sensor's primary radar interfaces, as defined in 3.5.2 of the main body of this document. At most one of the types of primary radar defined there will be simulated during any simulation run. ARIES shall be capable of transferring data over any of these interfaces at the maximum rates required of the Mode S sensor. It shall be possible for the ARIES software to transmit arbitrary data content over any of those interfaces.

90.3.2.1.5 Time-of-year interface.- ARIES shall be able to read the Mode S sensor's time-of-year clock via the interface specified in 3.5.6 of the main body of this document. The purpose of this interface is to provide time data which can be recorded by the ARIES data recording function (3.7). This allows ARIES recorded data to be correlated with data recorded by the Mode S sensor.

90.3.2.2 Interfaces to other ARIES.- The contractor shall provide each ARIES with interfaces for simultaneous communication with up to two other ARIES units. These interfaces shall be capable of supporting the requirements of 3.9.

90.3.2.3 Operator interfaces.

90.3.2.3.1 Operator's terminal.- An operator's terminal shall be provided identical in type to the one specified for the sensor in 3.8.3.1 of the main body of this document.

90.3.2.3.2 Printer.- A printer shall be provided identical in type to that required for the programming support facility defined in 3.8.3.1 of the main body of this document.

90.3.2.3.3 Magnetic tape unit.- A magnetic tape unit shall be provided, identical in type to those specified for the sensor in 3.8.3.1 of the main body of this document.

90.3.3 Simulated transponder behavior.

90.3.3.1 ATCRBS transponders.- ARIES shall be capable of simulating the RF behavior of ATCRBS transponders as specified herein.

90.3.3.1.1 Interrogation types.- Simulated ATCRBS transponders shall be capable of responding to the following interrogation types:

- Mode A (without the P4 pulse)
- Mode A ATCRBS/Mode S All-Call
- Mode A ATCRBS-Only All-Call
- Mode C (without the P4 pulse)
- Mode C ATCRBS/Mode S All-Call
- Mode C ATCRBS-Only All-Call
- Mode 2

These interrogation types are defined in the U.S. National Standard for the IFF Mark X (SIF) Air Traffic Control Radar Beacon System (ATCRBS) Characteristics (herein referred to as the ATCRBS National Standard) and in the Mode S National Standard.

90.3.3.1.2 Reply types.- Simulated ATCRBS transponders shall be capable of generating Mode A, Mode C, and Mode 2 replies, including the SPI pulse, as defined in the ATCRBS National Standard. It shall be possible for the ARIES software to set any data pattern into any reply.

90.3.3.1.3 Transponder behavior.- A simulated ATCRBS transponder shall reply to all interrogations of the types specified in 90.3.3.1.1 with the corresponding reply type (i.e., a Mode A reply for a Mode A interrogation) unless one or more of the following conditions holds:

- a) At the time of the interrogation the transponder azimuth lies outside the antenna beam. For this purpose the antenna beam edges are defined by the points where $|\Delta/\Sigma| = 2$.
- b) Generation of the reply would require a fourth reply generator (90.3.3.5).
- c) The specified reply probability (90.3.3.3.1.5) for the transponder is less than one, and the transponder randomly fails to reply in accordance with that reply probability.

- d) The slant range of the transponder is less than 1 nmi.
- e) The interrogation is a mode 2 interrogation and the transponder is not designated as being mode 2 equipped.

90.3.3.2 Mode S transponders.- ARIES shall be capable of simulating the RF behavior of Mode S transponders as specified herein.

90.3.3.2.1 Interrogation types.- Simulated Mode S transponders shall be capable of responding to the following interrogation types, defined in the Mode S National Standard:

- Mode A ATCRBS/Mode S All-Call
- Mode C ATCRBS/Mode S All-Call
- Mode S short interrogation (56 bits)
- Mode S long interrogation (112 bits)

All data bits of all Mode S interrogations shall be available to the software.

90.3.3.2.2 Reply types.- Simulated Mode S transponders shall be capable of generating the following reply types, defined in the Mode S National Standard:

- Mode S short reply (56 bits)
- Mode S long reply (112 bits)

It shall be possible for the ARIES software to set any data pattern into any reply.

90.3.3.2.3 Transponder behavior.- In the following, references to Mode S interrogation and reply data fields and protocols are made by means of names and abbreviations defined in the Mode S National Standard.

90.3.3.2.3.1 Reply protocol.- For all interrogation types a reply shall be generated or not as per the Mode S National Standard unless one of the conditions specified in 90.3.3.1.3 holds, in which case no reply shall be generated. The simulated transponders shall be equipped to respond only to interrogations with UF codes of 4 (surveillance, altitude), 5 (surveillance, identity), 11 (Mode S-only All-Call), 20 (Comm-A, altitude), 21 (Comm-A, identity), and 24 (Comm-C). However, nothing in the ARIES design shall preclude adding the ability to respond to other UF codes by means of software modifications to ARIES should processing for such codes be defined at a later date. The contents of the control and protocol fields (first 32 bits) of each reply shall be determined by ARIES based on both information contained in the

interrogations and the traffic model. Specific requirements are set forth in the following paragraphs, however the capability to respond to additional protocol requirements by means of software modifications to ARIES shall not be precluded by its design.

90.3.3.2.3.2 Lockout protocol.- Simulated Mode S transponders shall support the non-selective all-call lockout protocol as well as the multisite all-call lockout protocol.

90.3.3.2.3.3 Squitter replies.- Simulated Mode S transponders shall not generate squitter replies.

90.3.3.2.3.4 Flight status.- The content of the flight status (FS) field of Mode S replies shall be controlled by the traffic model. It shall be possible to specify any value for this field.

90.3.3.2.3.5 Capability reporting.- The content of the CA field of the all-call reply shall be controlled by the traffic model. It shall be possible to specify any value for this field. If the sensor should request an extended capability report, the resulting report shall be as specified by the traffic model.

90.3.3.2.3.6 Utility message.- The UM field of simulated transponder replies shall report the multisite reservation status for Comm-B, Comm-C, or Comm-D messages as specified in the Mode S National Standard.

90.3.3.2.3.7 Comm-A Protocol - Simulated Mode S transponders shall accept, but need not further process, Comm-A messages.

90.3.3.2.3.8 Comm-B protocol.- The simulated Mode S transponders shall support both the air initiated and ground initiated Comm-B standard and multisite protocols. The contents of the MB field required by the extended capability report shall be under control of the traffic model. The MB field for all other Comm-B replies shall be a constant determined by the traffic model.

90.3.3.2.3.9 ELM protocol.- Simulated Mode S transponders shall support both the uplink and the downlink ELM standard and multisite protocols. However, the MC field data content shall be ignored except as required to support the protocols. The MD fields of the replies shall contain constant data for all transponders and all replies, except as required to support the protocols. Downlink ELM requests shall be initiated under the control of the traffic model. It shall be possible to specify any number of downlink segments up to 16.

90.3.3.2.3.10 Reply probability.- The reply probability specified in the PR field of a Mode S-only All-Call shall be multiplied by the reply probability specified by the traffic model for a simulated Mode S transponder (90.3.3.1.5)

and the resulting probability compared to a value obtained from a pseudo random number generator to determine whether a reply will be generated to that all-call from that transponder. The lockout override function of the PR field shall be implemented.

90.3.3.2.3.11 Altitude and identity codes.- The contents of the AC and ID reply fields shall be controlled by the traffic model. It shall be possible to set arbitrary values into these fields.

90.3.3.3 Transponder parameters and simulated accuracy.- Transponder parameters shall be controlled by the traffic model (90.3.6). The parameters for each transponder will be updated periodically from the traffic model file.

90.3.3.3.1 Parameters common to ATCRBS and Mode S transponders.

90.3.3.3.1.1 Time.- The time at which the transponder state information is accurate shall be specified with a resolution at least as fine as 10 msec.

90.3.3.3.1.2 Range and range rate.- It shall be possible for a simulated transponder to have a range of from 1 to 255 nmi., and the range resolution shall be at least as fine as 1 range unit (Ru) as defined for the sensor. It shall be possible for a simulated transponder to have a range rate of from -600 Kt to +600 Kt (negative rate shall mean the transponder is approaching the sensor) and the range rate resolution shall be at least as fine as 0.25 Ru/sec.

The time of any simulated transponder reply transmission from ARIES relative to the time of the soliciting interrogation shall be correct for the current range of the corresponding simulated transponder within a time interval corresponding to 1 Ru. The appropriate transponder turnaround delay as specified in the ATCRBS National Standard and the Mode S National Standard shall be included in calculating the reply time. The range value to be used in calculating the reply time shall be obtained by extrapolating the transponder range to either the system time at the moment the interrogation is received or to the nearest system time at which the simulated transponder is predicted to be on the antenna boresight. The extrapolation shall be done by means of the equation:

$$\text{Extrapolated range} = \text{range} + (\text{extrapolation time} - \text{range time}) \times (\text{range rate}).$$

Range adjustment need not be made to account for cable lengths between the sensor and ARIES.

90.3.3.3.1.3 Azimuth and azimuth rate.- Simulated transponder azimuth shall be specified relative to the common north point used by ARIES and the sensor (3.2.1.3). It shall be possible for a simulated transponder to be at any

azimuth, and the azimuth resolution shall be at least as fine as 1 azimuth unit (Au) as defined for the sensor. It shall be possible for simulated transponders to have azimuth rates in the range from $-1/6$ to $+1/6$ radian/second. Positive azimuth rates shall correspond to motion in the direction of antenna rotation. The resolution in azimuth rate shall be at least as fine as 0.25 Au/sec.

The relative levels and phase of the Σ and Δ signals for any simulated transponder's reply shall be correct for the offboresight angle of the simulated transponder at the time of reply, such that in the absence of interference the sensor will obtain the correct azimuth for the simulated transponder within ± 3 Au. The transponder azimuth used in calculating the offboresight angle shall be obtained by extrapolating the transponder azimuth to either the system time at the moment the interrogation is received, or to the nearest system time at which the simulated transponder is predicted to be on the antenna boresight. The extrapolation shall be done by means of the equation:

$$\text{Extrapolated azimuth} = \text{azimuth} + (\text{extrapolation time} - \text{azimuth time}) \times (\text{azimuth rate})$$

This extrapolated transponder azimuth minus the antenna azimuth at the time the reply is generated shall be used as the offboresight angle. In order to generate the appropriate relative Δ and Σ signal levels with sufficient accuracy, this offboresight angle shall be used to index a lookup table which contains the appropriate level setting control values for each offboresight angle between the $|\Delta/\Sigma| = 2$ points. This table shall be produced by the calibration procedure specified in 90.3.11.

90.3.3.3.1.4 Power.— The reply level on the Σ channel shall be controllable over the range from -20 dBm to -83 dBm as referenced to the sensor's RF port. Adjustments shall be provided to correct for cabling losses between the sensor and ARIES, such that the maximum level transmitted by ARIES appears to the sensor identical to a signal of -20 dBm at the sensor's RF port. Both these adjustments and the simulated transponder power shall have a resolution at least as fine as 1 dB.

The Ω signal level shall be manually adjustable over a range from 10 to 25 dB below the Σ signal level, in steps of 1 dB. This level will be adjusted to approximate the relative Σ and Ω antenna gain of the Mode S sensor's antenna.

The power level specified by the traffic model will be adjusted for transponder range and elevation angle at the time the model is created. For each simulated transponder reply ARIES shall add a correction due to the fall off in the sensor antenna gain away from boresight. This correction shall be

solely a function of offboresight angle, shall match the sensor's antenna pattern on a plane through the peak of the beam within 1 dB, and shall be obtained by means of a table lookup.

90.3.3.3.1.5 Reply probability.- The reply probability of each simulated transponder shall be controllable over the range from 0 to 1 in steps of 1/15. If a reply probability of 0 is specified, no replies shall be generated for that simulated transponder. If a reply probability of 1 is specified, replies shall always be generated when the other reply conditions specified in 90.3.3.1.3 or 90.3.3.2.3 (depending on transponder type) are satisfied. At intermediate values of reply probability, a pseudo-random number generator shall be used in conjunction with the specified reply probability to determine if a reply will be generated, given that the other reply conditions are satisfied.

90.3.3.3.1.6 Identity code.- All simulated transponders (both ATCRBS and Mode S) will be assigned a unique 24 bit identity code by the traffic model. Furthermore, these codes will be unique within the least significant 12 bits. This code shall be used to associate traffic model data with the appropriate simulated transponder, and to identify a simulated transponder's data in the ARIES data recording (90.3.7). Simulated Mode S transponders shall use the entire 24 bit code as their Mode S address.

90.3.3.3.1.7 Track drop flag.- It shall be possible to indicate via a traffic model record that a transponder is to be dropped from the simulation.

90.3.3.3.2 ATCRBS Transponder Parameters - The mode A (identity), mode C (altitude) and mode 2 reply codes of each simulated ATCRBS transponder shall be obtained from the traffic model. It shall be possible to specify the value of each reply data bit individually, including the X and SPI bits. In addition, it shall be possible to indicate whether or not a simulated transponder is equipped to respond to mode 2 interrogations.

90.3.3.3.3 Mode S transponder parameters.- In addition to the basic parameters: described above, the following parameters, described in 90.3.3.2.3, shall be provided by the traffic model for simulated Mode S transponders:

- Flight Status (FS field)
- Capability (CA field)
- Extended Capability report (MB field)
- Downlink Request (DR field)
- Comm-B Data Link (MB field) including multisite protocol
- Comm-D Extended Data Link (MD field) including multisite protocol
- Altitude Code (AC field)
- Identity Code (ID field)

90.3.3.4 Interrogation rates and patterns.- In general, ARIES shall be capable of operating as specified herein in any interrogation environment generated by a correctly operating Mode S sensor (with either single or dual face antenna) operating within its capacity limits as specified in 3.3.2.5 of the main body of this document. However, the following are typical minimum spacings that will occur between the specified interrogation types (measured between the leading edges of the P1 pulses):

Successive ATCRBS/All-Call interrogations 2.5 msec.
(assumes such successive interrogations are only used
on back-to-back sensors with a 255 nmi. listening interval)

ATCRBS/All-Call to Mode S 0.7 msec.
(assumes a 60 nmi. listening interval for ATCRBS)

Mode S to ATCRBS/All-Call 197.0 usec.
(allows for an interrogation, turnaround time, and
a short reply)

Mode S to Mode S (back-to-back short interrogations) 64.0 usec.

Mode S-only All-Call to ATCRBS-only All-Call 35.0 usec.

The contractor may assume that the ATCRBS/All-Call interrogations occur in a regular repetitive pattern and therefore that the time, mode, etc., of future interrogations can be predicted. If the mode (A, C or 2), the antenna face (front or back) and the interval since the preceding interrogation are used to identify individual interrogations, it may be assumed that this pattern will repeat with a period of at most 20 interrogations. If the contractor makes use of this assumption, however, he shall also provide for the case where the sensor stops interrogating for a period of time in order to accomplish failure recovery as specified in 3.9 of the main body of this document. He shall also allow for the possibility that interrogations may be jittered as specified in 3.4.1.2.3.2 of the main body of this document.

After recovery, the sensor will transmit the same interrogation pattern but it shall not be assumed that the pattern after recovery is synchronized in time or type of interrogation with the pattern being transmitted before the failure.

It may be assumed that the Mode S sensor will not exercise its mode 4 interrogation capabilities as specified in Appendix V of this document.

90.3.3.5 Reply generators.- ARIES shall have three independent reply generators capable of generating either ATCRBS or Mode S replies. These shall be capable of generating simultaneous replies or any overlapping pattern of up

to three replies. The Σ outputs of the reply generators shall be summed together with each other and with the fruit reply generator Σ outputs (90.3.4.2) to generate the composite Σ signal output by ARIES. The Δ and Ω signals shall be summed similarly. Each reply generator shall be capable of generating successive back-to-back replies with a gap of no more than 1 usec between the trailing edge of the final pulse position of the first reply and the leading edge of the initial pulse position of the second reply. The controlling circuitry for these reply generators shall permit any reply pattern.

With a properly operating Mode S sensor, overlapping ATCRBS and Mode S all-call replies will occur only during ATCRBS/All-Call listening intervals. Replies to discrete Mode S interrogations will not overlap. The traffic models used with ARIES will on occasion specify aircraft positions that would cause more than three simultaneous replies to be generated. In this case, ARIES shall not generate those replies where, at the instant the reply is to begin, no reply generators are free (see 90.3.3.1.3).

The three reply generators shall be offset from each other in frequency, in order to avoid problems of coherent interference. One generator shall be at 1090 MHz and the other two shall be offset \pm 500 KHz on either side of 1090 MHz.

90.3.4 Simulated fruit replies.

90.3.4.1 ATCRBS fruit replies.- ARIES shall have three independent ATCRBS fruit reply generators. These shall also be independent of the reply generators for simulated transponders, as specified in 3.3.5, but shall be identical in capabilities. The Σ outputs from the fruit reply generators shall be summed with each other and with the corresponding Σ signals from the simulated transponder reply generators to generate the composite Σ signal output of ARIES. The Δ and Ω signals shall be summed similarly.

ARIES shall be capable of total average ATCRBS fruit rates of from 0 to at least 50,000 fruit/second. Software shall be able to specify the average fruit rate to be generated with a resolution at least as fine as 1000 fruit/second. The average fruit rate to be used for any given test shall be obtained from the traffic model.

Fruit reply inter-arrival times shall be exponentially distributed, that is, the probability of the interval between the leading edges of two successive F1 pulses being between t and $t + dt$ shall be;

$$P(t) = \lambda e^{-\lambda t} dt$$

Where λ is the average fruit rate as specified above. This distribution may be distorted, particularly at high fruit rates, by the limitation to three fruit reply generators.

The relative levels and phase of the Δ and Σ signals of fruit replies shall be such as to give an approximately uniform distribution of apparent reply offboresight angles between the $|\Delta/\Sigma| = 2$ points of the antenna beam.

Both simulated mainbeam fruit and simulated sidelobe fruit shall be generated. The fraction of mainbeam fruit shall be controllable by software over the range from 0 to 1 in steps of 1/255. The fraction to be used for a particular test shall be obtained from the traffic model. Individual replies shall be randomly selected as mainbeam or sidelobe replies.

For mainbeam fruit, the Σ channel signal level as referred to the sensor's RF port shall be randomly chosen according to the distribution:

$$P_{m1} = (-20 - 20 \log r_{m1}) \text{ dBm}$$

where r_{m1} is random and uniformly distributed between 1 and 100. For sidelobe fruit the equivalent distribution is:

$$P_{s1} = (-55 - 20 \log r_{s1}) \text{ dBm}$$

where r_{s1} is random and uniformly distributed between 1 and 32. The resolution in power level shall be 1 dB.

The Ω signal level shall be manually adjustable over a range from 10 to 25 dB below the Σ signal level for mainbeam replies, in steps of 1 dB. This level will be adjusted to approximate the relative Σ and Ω antenna gains of the Mode S sensor's antenna. For sidelobe replies the corresponding Ω levels shall be 25 to 10 dB above the Σ signals. That is, if $r_{m1} = r_{s1}$ for a mainbeam and sidelobe reply respectively, the Ω signal level shall be the same for each, but by the formulas above the sidelobe reply Σ channel level shall be 35 dB below that of the mainbeam reply.

The reply codes of simulated fruit replies shall be uniformly distributed over all possible reply codes, except that the X bit and the SPI bit shall always be zero.

90.3.4.2 Mode S fruit replies.- ARIES shall have a single Mode S fruit reply generator, independent of all other simulated transponder and fruit reply generators, but identical in capabilities. The Σ , Δ , and Ω output of this reply generator shall be summed with the corresponding outputs of all the other reply generators. The Mode S fruit reply generator shall be capable of average reply rates of from 0 to 500 replies/second. The rate shall be controllable by software with a resolution of 10 fruit/second. The average Mode S fruit rate to be used for any given test shall be obtained from the traffic model.

The inter-arrival times for Mode S fruit shall be exponentially distributed with the specified average rate, as described in section 3.4.1 for ATCRBS fruit replies. The apparent offboresight angles shall be as for ATCRBS fruit replies. The same parameters shall be used to define the fraction of mainbeam versus sidelobe fruit, the same I power distributions shall be used, and the same relative Ω levels shall be used, as defined for ATCRBS fruit replies.

Both long and short Mode S replies shall be generated. The fraction of long replies shall be controlled by software over the range 0 to 1 with a resolution of 1/15. The value to be used for a particular test shall be obtained from the traffic model. The 56 or 112 bit data content shall be randomly generated from reply to reply. The random data may be transmitted as generated or passed through the Mode S reply parity encoding function.

90.3.5 Simulated radar reports.- ARIES shall generate simulated primary radar reports for all simulated aircraft. A report shall be generated for each simulated aircraft on each scan subject to a radar blip/scan ratio. The blip/scan ratio shall have a value of 0 to 1 with a resolution of 1/31. The value to be used for a particular test shall be specified by the traffic model. A value of 1 shall result in a radar report for each aircraft on each scan. A value of 0 shall result in no radar reports being generated. Intermediate values shall result in the specified average blip/scan ratio, with individual replies being deleted on a pseudo-random basis.

Radar reports shall be transmitted to the sensor following the front antenna boresight crossing of the simulated aircraft, but within the specified time limits for sensor radar processing in order that they not be discarded by the sensor. The reported range and azimuth shall be those obtained from the traffic model as extrapolated to the time of boresight crossing. The same extrapolation method shall be used as for beacon replies. Radar report fields other than range and azimuth shall be given constant values for all reports from all aircraft. All fields provided by the type of primary radar being simulated shall be provided by ARIES. The constants used shall be chosen by the contractor with the approval of the FAA.

ARIES shall not generate other radar report types such as weather map, radar status or real time quality control (RTQC) reports.

90.3.6 Traffic model.- The traffic model shall control the parameters of all the simulated transponders, updating these periodically. It also shall control the fruit generator parameters. Traffic models to be used for government required testing will be provided by the government. Other traffic models the contractor may wish to use for system testing shall be provided by the contractor.

Traffic models shall be input to ARIES from 9-track tape. Data from the tape may be read into ARIES in real time during a simulation, or may be copied to another mass storage device offline prior to the simulation, and this other

device used to provide the data in real time. Any such mass storage device shall be sufficient to accomodate a 30 minute simulation involving 700 aircraft.

The contractor shall define the detailed tape formats, subject to the constraints herein. Each logical record shall specify the state of one simulated transponder or the desired fruit parameters at an instant in time. Each record shall contain a time field specifying this time, with a resolution at least as fine as 10 msec., and a range of from 0 to 1 hour. The logical records will be sorted in increasing time order. No more than 5 logical records will have any given time value.

Each simulated transponder record shall contain at least the following fields, defined in detail in 90.3.3.3.1:

- Range
- Range rate
- Azimuth
- Azimuth rate
- Power
- Reply probability
- Identity code
- Track drop flag

In addition, simulated ATCRBS transponder records shall contain the following fields, defined in detail in 3.3.3.2:

- Mode A code
- Mode C code
- Mode 2 code
- Mode 2 equipage

Simulated Mode S transponder records shall contain, in addition to the basic fields, the fields listed and defined in 3.3.3.3.

The contractor may assume that the parameters for each transponder in the simulation will be updated once every four seconds, approximately. However, no correlation shall be assumed between update times and antenna rotation.

Fruit parameter records shall contain at least the following fields, defined in detail in 3.4:

- Average ATCRBS fruit rate for each of 32 $11\ 1/4^\circ$ sectors
- Average Mode S fruit rate for each of 32 $11\ 1/4^\circ$ sectors
- Fraction of fruit in the main beam
- Fraction of Mode S fruit which are long replies

The fruit parameters will be updated at least once every ten seconds.

The transponder and fruit data on a traffic model tape shall be preceded by a tape label record, consisting of up to 1000 bytes of alphanumeric data. This label will be used to identify the nature of the environment to be simulated, and will be used to associate model tapes with ARIES data recording tapes (see 3.7).

90.3.7 Data recording.- ARIES shall record certain data during simulation to aid in analyzing Mode S sensor performance and also to aid in troubleshooting both ARIES and the Mode S sensor. Data shall be recorded on 9 track tape. The data may initially be recorded in real time on some other form of mass storage and copied offline to 9 track tape. The contractor shall define the detailed tape formats subject to the constraints herein. It shall be possible to determine where the first complete logical record (data block) begins in each physical record, independent of data in other physical records. The data recording shall operate as specified herein for all traffic models within ARIES' capacity, as defined in 90.3.1.1.

The contractor shall provide a program or programs for formatted dumping of ARIES data tapes to a printer. These dump programs shall run on both the ARIES equipment and on the programming support equipment defined in Appendix II of this specification. The data block types (defined below) to be dumped shall be individually selectable by the operator as shall the start and end times between which data shall be dumped. Each block dumped shall appear on a separate line or lines, and blocks shall appear in the order of the times contained in the block header (defined below). Individual fields within a block shall be converted to appropriate engineering units.

Each logical record (data block) shall contain header information followed by one or more words of related data. The header information shall consist of:

- a) The time-of-year at which the recording was performed as obtained from the sensor's time-of-year interface. The hour and fields of greater significance may be left out, being recorded in data block type (e) below.
- b) A data block type code which defines the sort of data contained in the block.
- c) The number of words in the logical record.

At least the following data categories and contained fields shall be recorded:

- a) All interrogations:
 - 1) Time of arrival. The clock used shall have a resolution at least as fine as 1 μ sec, and shall have an unambiguous interval of at least 4 msec.

- 2) Antenna azimuth at interrogation time, LSB 1 Au.
 - 3) Antenna indicator (front or back antenna).
 - 4) Interrogation type (Mode A, Mode C, Mode 2, short Mode S, long Mode S).
 - 5) For Mode S interrogations, 56 or 112 bits of data.
- b) All replies to interrogations (fruit replies shall not be recorded):
- 1) Time of reply. The same clock shall be used as for interrogations.
 - 2) Reply type (ATCRBS, short Mode S, long Mode S)
 - 3) Transponder azimuth or offboresight angle at reply time (LSB 1 Au).
 - 4) Reply power before correction for offboresight angle.
 - 5) Reply data content: 14 bits including X and SPI for ATCRBS replies. 56 or 112 bits for Mode S replies.
 - 6) For ATCRBS replies, the least significant 10 bits of the transponder's 24 bit identity code (90.3.3.3.1.6). For Mode S transponders this will be included in the reply data (e).
- c) All radar reports: The entire data content shall be recorded.
- d) All inter-ARIES messages: The entire data content of all messages sent to or received from other ARIES while running in the multi-site configuration shall be recorded.
- e) Sensor time-of-year: This shall be recorded as the first item on the data tape to establish a correlation between the sensor time-of-year and the times used in the data recording header information. It shall also be recorded at least once every ten seconds. It shall include the traffic model time, section 90.3.6, that corresponds to the recorded time-of-year.
- f) Operator inputs.

- g) Manual switch settings on the ARIES equipment which may affect the simulation results.
- h) Counts or other indicators of error conditions detected by the software.
- i) The calibration table(s) used to convert offboresight angles to relative Δ vs I signal levels and to I power corrections. Also any other table contents which might vary from experiment to experiment and which could significantly affect simulation results.
- j) The traffic model label data (90.3.6) (however, traffic model data other than the label shall not be recorded).

The contractor shall suggest any other data categories to be recorded which he considers appropriate to carrying out the purpose of the ARIES equipment, and in particular of the data recording function.

90.3.8 Operator commands.- The ARIES operator shall be able to control the operation of the ARIES from the operator's terminal (90.3.2.3.1). At least the following capabilities shall be provided:

- a) The ability to initialize to an arbitrary time on the traffic model as the starting time for the simulation. At the time the simulation starts, the simulated transponder parameters and fruit parameters, as read from the traffic model, shall be identical to those that would have been obtained at that point in time by running the simulation from time zero.
- b) The ability to start the simulation. The simulation shall commence at the first antenna northmark crossing following the issuance of this command.
- c) The ability to stop the simulation. This shall be done in such a way that ARIES can immediately and conveniently be reinitialized as in (a).
- d) The ability to create simulated aircraft from the console. It shall be possible to create them at arbitrary ranges and azimuths. Similarly all other aircraft parameters that are obtained from the traffic model shall also be controllable over their full range.
- e) The ability to drop aircraft created by the operator.

- f) The ability to control from the terminal those fruit generation parameters that are controlled from the traffic model.
- g) The ability to enable and disable the traffic model. When the model is enabled it shall update the transponder and fruit parameters as defined herein. When disabled, ARIES shall not read the traffic model, and the only source of transponder and fruit parameters shall be the operator's terminal. It shall not be possible to enable or disable the traffic model while an environment simulation is in progress.
- h) The ability to monitor certain system state information in order to determine the current system status and to monitor the system operation during a simulation run. This information shall include but not be limited to the current number of ATCRBS and Mode S aircraft, fruit parameter settings, equipment switch settings, summaries of error conditions encountered, and an indication of the amount of loading on the ARIES computer(s).

At the operator's option, all terminal input and output shall be recorded on the printer for record keeping purposes. This data may be recorded on a mass storage device during real time operations and transferred to the printer off line.

90.3.9 Inter-site communications.- Mode S transponders have certain internal state information corresponding to the various control and datalink protocols in which they participate. To the extent ARIES simulates such protocols, it must retain such state information for each simulated Mode S transponder. In a multi-site simulation a single Mode S transponder may be visible to more than one sensor. The ARIES located at each such sensor will therefore have to maintain state information for that transponder. Some of this information is controlled entirely by the traffic model, but some of it is affected, at least in part, by interrogations from the sensors. Changes caused in this way at one site must be reflected in the simulated transponder state at all sites.

The contractor shall design an inter-ARIES communication network and message formats such that state changes due to sensor interrogations at any site are reflected in the corresponding simulated transponder's state at all other sites where it is visible. Changes due to traffic model inputs shall not be communicated over this network. At most 0.1 second shall elapse between the receipt of the interrogation causing the change and the time when all ARIES in the network have updated the corresponding transponder state.

The multi-site simulation capabilities of ARIES shall be capable of operating up to the maximum single site traffic capacities specified in 90.3.1.1.

A second function of the inter-site communications network shall be to provide for network control and synchronization. When multiple ARIES units are connected in a network, the operator commands of 3.8 for initialization, starting, and stopping the simulation shall control the entire network. It shall be possible to exercise this control from any ARIES site in the network. In the case of the start command, the network as a whole shall be started at the next northmark crossing of the antenna at the site where the command was issued. All other sites will also start at that time, rather than waiting for their own north crossings.

The inter-ARIES communication system shall provide for periodic system checks that all ARIES sites are maintaining system clock synchronization, where the system clock is defined to be the clock which determines when traffic model data is to take effect. Clock synchronization shall be maintained within 100 msec. An error condition shall be indicated on the data recording and operator status messages if this condition is not maintained.

The unavoidable delays in the transmission of state information among sites can at times give rise to anomalous simulation results (i.e., unlike those that would have been observed in a live flight test where the transponder state is represented at a single point). The contractor shall analyze the effects of such delays in light of Mode S protocols and Mode S sensor network behavior, shall point out test conditions where realistic multi-site simulation is difficult or impossible due to "race conditions" or other timing related problems, and shall suggest guidelines for multi-site testing that will lead to acceptable simulation behavior.

90.3.10 Self-test capabilities.- Due to the importance of ARIES to Mode S sensor testing, and the complexity of the ARIES system, extensive self testing capabilities are required of the ARIES equipment. These provide for initial equipment checkout, for maintenance diagnostic assistance, and for confirmation of correct operation prior to and following simulation runs.

For all standard commercial equipment such as CPU's, tape drives, disks, etc., the standard diagnostics provided by the manufacturer or supplier shall be available to be run by the ARIES operator. If diagnostics are not provided by the manufacturer or supplier, diagnostic programs shall be provided by the contractor.

All special purpose digital equipment designed for ARIES shall be provided with diagnostic modes and data paths and diagnostic software. The requirement shall be to automatically exercise all data paths between the computer and this equipment by writing data into buffers, registers, etc., and then reading the data back.

In addition to the above, special equipment shall be provided to perform loop testing of major ARIES subsystems. It shall be possible under diagnostic software control to transmit at 1030 MHz all interrogation modes and data patterns which can be processed by the ARIES receiver curcuitry, and to couple these into the normal receiver RF paths at an appropriate level. Diagnostic software shall be provided to use this feature to check receiver operation. It shall be possible to set this equipment into a free-running mode where a chosen interrogation is sent periodically without software intervention with a period of at least 4 msec. In conjunction with the azimuth simulation capability, the free running interrogation mode shall allow ARIES (both hardware and software) to run in its normal simulation mode without connection to a Mode S sensor. Limitations on traffic load may be required due to the higher than normal interrogation rate. This mode is useful for checkout of ARIES equipment and software when a Mode S sensor is unavailable.

It shall be possible under diagnostic software control to sample the I, A, and Ω signals at 1090 MHz after the point where all the individual reply generator signals have been summed. It shall be possible to sample the absolute amplitude of each signal with sufficient accuracy to determine that the level setting circuitry, and in particular the monopulse offboresight simulation, is working correctly. It shall be possible to measure the relative phase of I and A with sufficient accuracy to determine that the monopulse left/right of boresight circuitry is working correctly. It shall be possible to sample all reply data bits, for all reply types. It shall be possible to sample the time of the reply with the same resolution with which it is specified for the reply generators.

It shall be possible under diagnostic software control to generate individual replies from any of the simulated transponder reply generators or fruit reply generators in any of the reply modes and with any reply parameters and data content of which they are capable. Diagnostic software shall be provided to cycle each reply generator through all reply types, offboresight angles, and a variety of data content and reply times. This software shall use the reply sampling equipment to confirm correct operation of the reply generators. It shall be possible at the operator's option to produce tables of observed signal levels versus level settings on the ARIES printer.

A loop-back mode shall be provided for both the inter-ARIES and simulated radar links whereby data transmitted over these links shall be read back into the ARIES memory. Diagnostic software shall be provided to use this feature to check the operation of these links.

Diagnostic programs shall provide their output on the operator's terminal and, at the option of the operator, on the ARIES printer.

90.3.11 Calibration procedures.- The relative Δ vs Σ signal levels to be used by ARIES to simulate each offboresight angle shall be determined by means of a calibration procedure involving both ARIES and the Mode S sensor. Prior to the ARIES calibration, the sensor's monopulse table shall have been calibrated by means of the procedures described in 3.4.11 of the main body of this document. The ARIES calibration shall involve the transmission by ARIES of several replies at each Δ vs Σ signal setting of which it is capable. Calibration software in the sensor shall observe these replies and compute their apparent offboresight angle. The data for replies transmitted at the same level settings shall be averaged together, and the resulting information used to generate the necessary table of level settings as a function of desired offboresight angle. The contractor may use the sensor's interrogation link to close the loop between ARIES and the sensor and return the calibration data to the ARIES calibration software.

This space intentionally unused.

FAA-E-2716
APPENDIX IX

-IX-24-
(Last page of Appendix IX)

FAA-E-2716
APPENDIX X

-X-1-

APPENDIX X
MODE SELECT BEACON SYSTEM SENSOR
FAA 80'S MAINTENANCE CONCEPT

APPENDIX X

MODE SELECT BEACON SYSTEM SENSOR

FAA 80'S MAINTENANCE CONCEPT

100.1 BACKGROUND

100.1.1 Objectives.- The objectives of the maintenance program is to ensure that the overall mission needs are met and the total overall cost of ownership is minimized by incorporating a new method of designing, maintaining and supporting Airway Facilities equipment. This requires the process of translating mission needs, operational and support requirements into detailed engineering design requirements, that provide minimized Life Cycle Costs (LCC). Design requirements shall be developed through an interactive process which analyzes requirements and LCC to converge on a totally optimized system.

100.1.2 General design for the 80's.- The 80's maintenance program is based on conversion of all equipment to solid-state technology, use of remote maintenance monitoring of equipment and centralization of the work force with minimum preventative maintenance tasks. The primary consideration in design of the facilities and equipment is their ability to perform the intended function reliably. The concept allows the maintenance of an overgrowing inventory of equipment to be performed by a relatively small, technician work force. Repetitive and administrative tasks normally done by a technician are to be accomplished by a computer, thereby leaving the technician free to perform high level, decision oriented work. The central provisions of the program is the ability to remotely monitor the performance of a facility,

measure equipment parameters, predict imminent failures, and to make compensating adjustments or corrections. This requires sensors at the remote facility feeding up-to-date information over a telecommunications network to a central processor, located at an ARTCC, terminal facility, or sector office. It would collect, process, analyze data and present the necessary information to the technician via a portable terminal at the remote facility or where there is access to a telephone or stationary terminal at a work center. The level or degree to which these functions would be accomplished would vary by facility type.

100.2 Design characteristics

100.2.1 Maintenance system.- Facilities are classified as "remote" facilities or facilities at the Central Maintenance Facility.

a. Two Level Facility Concept.- Facilities are classified as "remote" facilities or facilities at the Central Maintenance Facility.

(1) "Remote" Facilities. The term "remote" does not necessarily imply an inaccessible location but one that is not proximate. Most facility types (VORTAC's, RCAG's, MLS's, ASR's) are classified as "remote facilities". These facilities shall require very few visits by personnel for repairs. On-site maintenance is restricted to periodic checks of equipment performance, cleaning of equipment, and removal and replacement of modules. The facility shall be designed for simplicity. Given a design choice, complexity shall be placed in the central facility where maintenance is most readily available. Provisions shall be included for remote monitoring and control of the remote facility.

(2) Central Maintenance Facility. The Central Maintenance Facility shall contain the centralized remote monitoring and control hardware to ensure availability of the system function. The central facility is equipped to repair modules, perform module level modifications, conduct performance tests on subsystem components associated with facilities and RMM system.

b. The Remote Maintenance Monitoring System (RMMS). The RMMS shall be used to remotely monitor, and automatically report on facility performance and provide control of some operations, thereby providing increased facility/equipment availability and minimizing routine equipment site visits by the technicians. The RMMS shall be used to effect savings in travel and to better utilize the technicians as an important, limited sector resource.

c. Documentation Actions.- The RMMS shall be designed to minimize routine documentation actions and automate manually prepared facility logs, outage reports, and other documentation.

100.2.2 System design.- The AF equipment will be influenced by several design characteristics. These characteristics which must be balanced against each other to optimize the system design and life cycle costs include: availability, functional performance, reliability, standardization and flexibility, expandability and adaptability, remote and central facility concept, maintainability, the environment and energy conservation.

a. Operational Availability and Reliability. The primary consideration in design of facilities and equipment is their ability to perform the intended function. Design decisions will be required to obtain the desired operational availability. Alternative methods such as overlapping coverage, high element or system reliability, and element or system redundancies must be considered. There are two general purposes for this approach: (1) the continuing need for increased availability of systems as the control and navigation of aircraft becomes more dependent on the system; and (2) the need to reduce design, acquisition, and operating costs of the system. Life cycle cost (LCC) analyses must be performed in order to optimize system design requirements vs costs.

b. Site Visitation. All remote equipment shall have a design goal of one maintenance visit per quarter. Site visits may be made by items composed of electrical and environmental technicians. Maintenance actions include both corrective maintenance (CM) and preventative maintenance (PM).

c. Standardization. Standardization of equipment elements shall be mandated to reduce not only LCC but, to reduce the skills necessary to maintain, operate, and support the system. Special purpose hardware shall be reduced or eliminated. The resulting systems are to be more dependent on the software and firmware that adapts the standard elements to the functions required. The two forms of standardization are major hardware elements used in several functional systems and major software and firmware elements within the system. The design of both hardware and software should be modularized so that they are less time consuming and less costly to modify.

d. Adaptability. System design shall provide for adaptability such that the standard system elements may be adapted to local requirements without modification of the elements themselves. They could be adapted by standard hardware or software adaptation.

f. Maintainability. Maintainability features shall be included in the design of equipment and systems. The features are to reduce repair time by enhancing the ability of the technician to diagnose a malfunction rapidly, to identify the defective part or module, and to replace it quickly with a new part. The types of features that shall be considered are internal online diagnostics that can isolate the failed module and automatically reconfigure a redundant element; modular design for redundancy and ease of maintenance

replacement for later offsite repair; built-in, test equipment; remote monitoring and control, and diagnostic provisions to maximize routine maintenance intervals, and test to detect imminent failures during controlled periods. There shall always be sufficient information for the technician to assess system performance and effect a correction where necessary.

(1) Built-In Diagnostics. Equipment performance specifications shall either identify the level of built-in diagnostics required and/or will call for trade-off studies to evaluate the cost effectiveness of specific levels of built-in diagnostics.

(2) Modularity. Shall be considered in design. Modularity is achieved through functional design by partitioning the system into physically and functionally self-contained units to facilitate fault isolation, removal, and replacement. Partitioning enables equipment units, assemblies, and sub-assemblies to be designed as discrete items or modules. The application of modular design allows the isolation of faults to a unit which may be removed from the equipment and are replaced with a spare module. The faulty module shall then be repaired at the Central Maintenance Facility maintenance hub minimizing online maintenance action.

(3) Remote Maintenance Monitoring System (RMMS). Functions to be implemented at the present time are:

- 1 monitor and alarm
- 2 certification
- 3 remote control
- 4 record keeping
- 5 trend analysis
- 6 failure anticipation

Future functions are:

- 7 diagnostics
- 8 remote adjustments
- 9 a problem/solution file

The RMMS shall consist of the following:

1 A maintenance processor subsystem (MPS) that functions as the "master station" RMM central processor.

2 A telecommunications network (TCN) that enables telecommunications to and from the monitored facilities/equipment to the MPS.

3 Remote monitoring subsystem (RMS's) that function as the remote "alarm station" required to monitor and control the remote facility/equipment.

(4) Throwaway Concept. A predetermined throwaway concept for modules shall be considered based on cost and logistics. A trade-off shall be made during early design to determine whether small inexpensive modules shall be incorporated and designed throwaway or to design larger modules for a possible economy of equipment repair.

g. Minimum Preventive Maintenance. Equipment design shall minimize the number and frequency of periodic maintenance tasks. The resultant system characteristic shall minimize periodic maintenance tasks and minimized numbers of facility/equipment site visits. Periodic maintenance tasks and periodically shall be flexible enough to allow for periodic maintenance to be accomplished in conjunction with corrective maintenance tasks. Upon completion of the corrective maintenance and periodic maintenance tasks, the PM clock is reset, to provide the appropriate time interval until the next PM visit or CM, whichever comes first. Remote equipment has a design goal of one maintenance visit per quarter year.

h. Environmental. Alternatives for environmental equipment shall include RMM capability, extended time between preventive maintenance actions and failures, reduced time to diagnose, trouble shoot and repair. Battery back up shall be considered in lieu of engine generators for particular equipment application.

i. Energy. Systems shall be designed for energy efficiency. Reuseable energy sources (solar, wind, etc.) for system power requirements shall be considered based on LCC analysis. This analysis shall be made during the early design stages.

100.3 Maintenance operational characteristics

100.3.1 Maintenance philosophy.- The Airway Facilities maintenance philosophy is developed around contemporary technologies incorporating automated remote facility maintenance and management techniques. It represents an emphasis on system integrity and productivity rather than intensive preventive measures. This is reflected in engineered maintenance planning during system development and the operational maintenance process.

a. Maintenance Planning. Maintenance planning and analysis shall be incorporated in the system development process and will document support requirements such as spare/repair parts, training, maintenance procedures, remote monitoring equipment, test equipment, and other support items for the system.

b. Definition of Maintenance Levels. Availability and reliability of airway facilities are to be the prime functional responsibilities of field maintenance personnel. Therefore, the following maintenance levels are established to effect maximum responsiveness, productivity, and efficiency in utilization of maintenance personnel and resources.

(1) Onsite Maintenance. Onsite maintenance shall be conducted in accordance with policy and guidance defined in the applicable maintenance directive (maintenance plan) for the airway facility, system, or equipment. It will consist of routines periodic maintenance and repair actions as required to maintain the airway facility in a fully operational status. The term "airway facility" includes the maintenance of all primary, secondary, and auxiliary equipment or systems that are necessary to support the total facility. Onsite maintenance shall also include nonroutine or repair actions in the form of system analysis of faults, troubleshooting, and testing in accordance with technical manuals, logic diagrams, or manufacturer's handbooks to identify faulty components, units or assemblies, and to effect repair.

(2) Central Maintenance Facility (CMF). Maintenance of LRI's will be accomplished in centrally located sector facilities which are equipped and staffed to repair modules, conduct performance tests on subsystem components and perform module level modifications on facilities and systems within their area of responsibility. The CMF will be equipped with specialized test equipment and tools, spare parts, and specialized diagnostic hardware/software required for repairing LRI's that are removed in accomplishment of onsite field maintenance activities.

In addition, the CMF will provide for the calibration of test equipment and RMM systems which include the RMM equipment at the remote sites. LRI's that require repair capability beyond the resources provided to the CMF will be forwarded by the sector to the designated vendor or Depot maintenance repair facility.

(3) Depot Maintenance. Depot maintenance facilities will provide support for repair, alignment, and calibration of complex equipment and modules requiring specialized equipment and procedures. This level provides the maintenance program with the capability for completely overhauling and rebuilding equipment as well as the performance of highly complex maintenance actions which are beyond the resources of the field maintenance organization. The depot also serves as the major logistics support facility for field accomplishment of onsite and CMF maintenance activities.

100.3.2 Maintenance organization

a. Airway Facilities Sectors. Airway Facilities sectors are the principal element in the field maintenance program. Typically, they have a

complement of approximately 100 people and provide onsite field maintenance, central repair facility capability, first level engineering support, logistics support, training, and administrative support under the management of a sector manager.

b. Regional Offices. The Regional Offices manage and provide overall policy guidance in the maintenance program to sectors, manage engineering activities, prepare cost estimates, and identify equipment and material for establishment programs.

c. National Field Support Group. The National Field Support Group provides second level engineering support with an emphasis on resolution of system-wide and national problems associated with system integration and implementations well as engineering support for resolution of difficult local problems.

d. Headquarters. FAA headquarters administers and manages the technical aspects of the NAS. It develops policy and procedures and is responsible for the acquisition and development of major NAS systems.

100.3.3 Maintenance management system.- The maintenance management system is a composite of the technical and technical management information necessary to manage the NAS. A large percentage is automated and interactive. Application of this data assists in assessing performance analysis of trends, reporting status, scheduling administration and technical functions.

100.3.4 Support.- From the view of an operational NAS facility, support is multifaceted. It includes documentation and analytical capabilities, provisioning of spare/repair parts, test and calibration equipment, and engineering assistance.

a. Documentation. The remote maintenance monitoring system (RMMS) shall be designed to minimize routine documentation action and prepare facility logs, outage reports, and other documentation.

b. Requisitioning. Requisition of spare and repair parts from the depot shall be accomplished through the use of RMMS/MPS system.

c. Repair Support. The majority of physical repair and calibration requirements are satisfied at the sectors CMF's. The depot provides capability to support special items which are not cost effective to service at CMF's. Responsibility for repair and the allocation of necessary test/calibration equipment and spares is identified during the acquisition portion of the maintenance planning activity.

d. Engineering Support. Support of an engineering nature to solve difficult problems and establish new systems is provided by the sectors. Each sector has this capability within its structure. This resource will be supplemented by regional capability. The National Field Support Group (NFSG) provides resolution to problems of system-wide nature.

100.3.5 Service certification.- Certification of NAS facilities shall be based on officially approved tolerances and limits for specified system parameters. These parameters indicate the quality of the service being provided to the user. The act of determining that these parameters are within prescribed tolerances and limits, is termed service certification.

a. Methods of Certification.

(1) Systems that employ remote monitoring have two methods of certification. Remote facility certification can be accomplished through: the RMM equipment on a regular basis by polling routines; on demand for the purposes of satisfying incident procedures; and by a less frequent scheduled requirement for onsite certification of the equipment and verification of normal operations of the remote monitoring equipment.

(2) Systems that are not remotely monitored are certified by a technician onsite, physically measuring the critical parameters. This is accomplished on a scheduled basis or as dictated by incident procedures.

100.3.6 Inspections

a. Technical Inspections.- These are systematic onsite inspections on a periodic basis. The frequency and scope of these inspections is determined by performance assessment.

b. Flight Inspections.- There are three types of flight inspections of facilities which radiate signals in the NAS. They are:

(1) Periodic - Determined by performance trends analysis and may be conducted from the site, RMM terminal or both depending on the scope.

(2) Commissioning - Required prior to certifying major systems for use in the NAS.

(3) Special - Required by administration incident investigations procedures.

100.3.7 Staffing and training.

a. Staffing. Staffing is based on the number of facilities and structures to be supported. The number of personnel to support new equipment

is determined by qualitative and quantitative factors. Standards for establishment of staffing levels accommodate the analytical nature on the positions as well as traditional direct work categories.

b. Training. FAA technicians have the comprehensive knowledge of theory and hardware necessary to perform analytical and corrective efforts in a manner demanded by the criticality of the NAS.

(1) FAA Academy Training - The FAA Academy in Oklahoma City conducts resident, in-depth, hands-on, training on specific hardware/software systems. They also develop multi-media courses to support sector training.

(2) Airway Facilities Sector - The sector conducts prerequisite and refresher training with multi-media training materials. These materials are designed to support the needs of predevelopmental, developmental, and journeymen technicians.

This space intentionally unused.

FAA-E-2716
APPENDIX XI

-XI-1-

APPENDIX XI

SENSOR CONFIGURATIONS FOR INITIAL IMPLEMENTATION

APPENDIX IX

SENSOR CONFIGURATIONS FOR INITIAL IMPLEMENTATION

110.1. SCOPE.

110.1.1 Scope.- This appendix specifies the sensor configurations that will be used at the time of initial implementation. Sensor-to-ATC interfaces are specified to identify the sensor features (specified in this document and its appendices) that are to be used at initial implementation. No new sensor functional capabilities are specified in the appendix.

110.2 DEFINITIONS.

(none)

110.3 REQUIREMENTS.

110.3.1 Initial ARTS-II/Mode S sensor interface.- The initial interfaces of the Mode S sensor with the ARTS-II facility will be essentially identical to the current ATCRBS input interface currently in use at these sites. In its initial installation, the Mode S system will be operated in the ATCRBS mode only.

At some future date the output from the Mode S system may be interfaced to a video reconstitutor. In such case the Mode S sensor would be site adapted to operate to a range of 60 nmi. The video reconstitutor would be serviced as a non-correlating user and would receive digital reports on all aircraft while the Mode S processor is operating. The output of the video reconstitutor would be input to the ARTS-II in lieu of the ATCRBS input currently received from a beacon interrogator.

In the event the video reconstitutor concept is employed, provision would be made to switch it out of service and return to a straight ATCRBS mode.

At the time of the Mode S sensor installation, an ARTS-II facility will be equipped with an ASR-7, ASR-8 or ASR-9 primary radar.

110.3.2 ARTS-II installed with ASR-9.- At sites where the ARTS II system is fed by an ASR-9 primary radar, the surveillance data from ASR-9/Mode S shall be input to a Surveillance and Communications Processor (SCIP), which will be used to drive ARTS II and ATC display equipment.

110.3.3 Initial ARTS-III/Mode S sensor interfaces.- The Mode S sensor, configured for operation to 60 nmi., shall interface with the ARTS-III through the ASR-9 primary radar. The Mode S sensor shall accept search and status data from the Moving Target Detector (MTD) of the ASR-9 (3.5.2.4.1). The sensor shall process the primary target reports from the ASR-9 together with its own beacon measurements to accomplish radar/beacon correlation. The Mode S sensor shall provide surveillance data to the ASR-9 for transfer to ATC (3.5.2.4.2).

A block diagram of the ARTS-III/Mode S interface is shown in Fig. XI-1.

110.3.4 9020 Mode S sensor interface.

110.3.4.1 No modifications to the CD-2.- This initial enroute configuration will utilize the Mode S sensor in its EI-5 mode (Appendix VI). ATCRBS beacon video from the Mode S sensor shall be input to the CD-2 in lieu of the output of the existing beacon interrogator.

A block diagram of this initial 9020/Mode S interface for a two channel system is shown in Fig. XI-2.

110.3.4.2 CD-2 modified for digital interface with Mode S.- If the CD-2 is modified to achieve a digital interface with the Mode S sensor, it will be used as a primary radar digitizer and its output will be provided to the Mode S sensor. The sensor shall perform radar/beacon correlation and shall output primary and radar reports to the 9020 in the current CD format. All beacon reports (for ATCRBS and Mode S aircraft) shall use the ATCRBS format.

A block diagram of the initial 9020/Mode S interface is shown in Fig. XI-3.

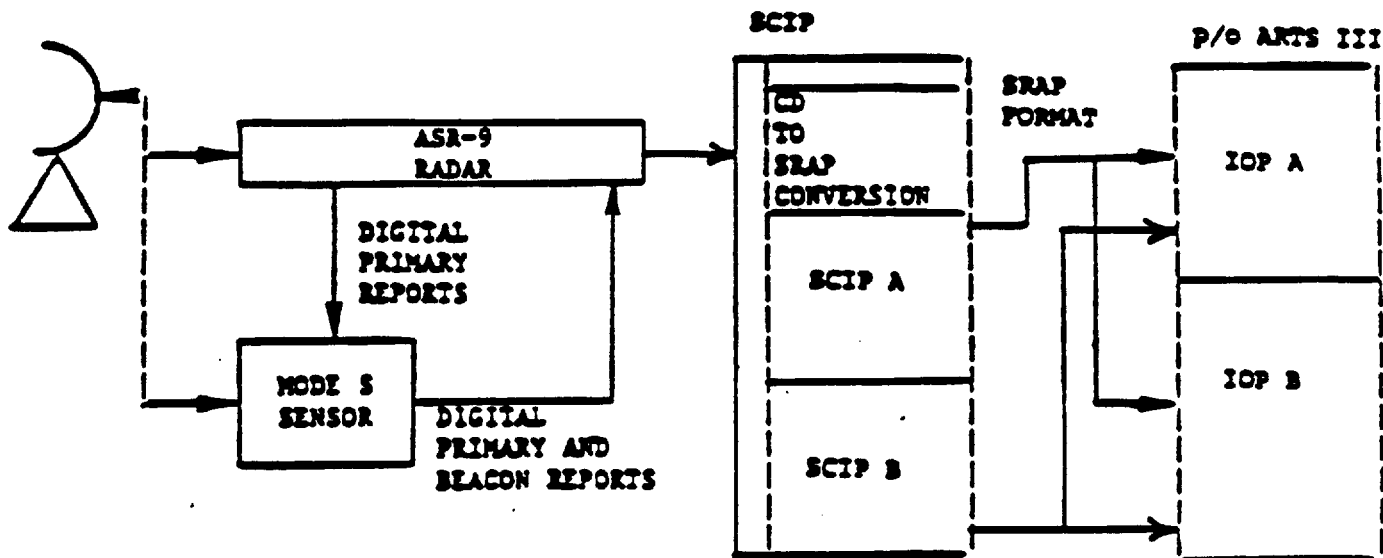


Fig. XI-1 Initial ARTS-III/Mode S Sensor Interface.

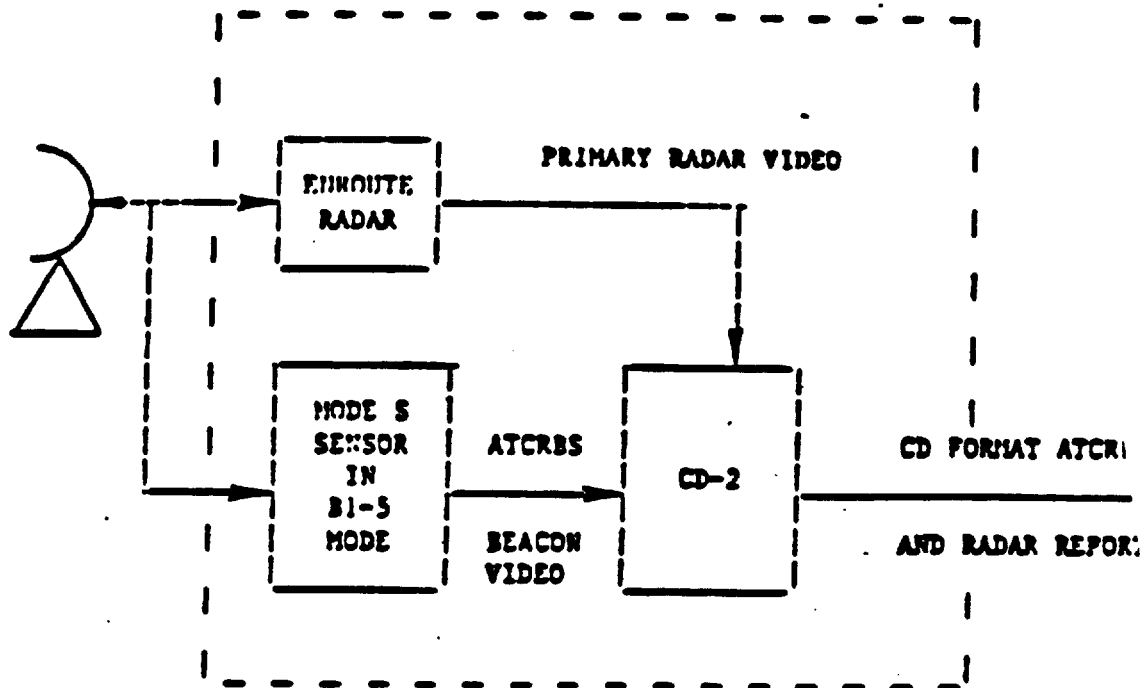


Fig. XI-2 Initial CD-2/Mode S Interface-Without CD-2 Modification.

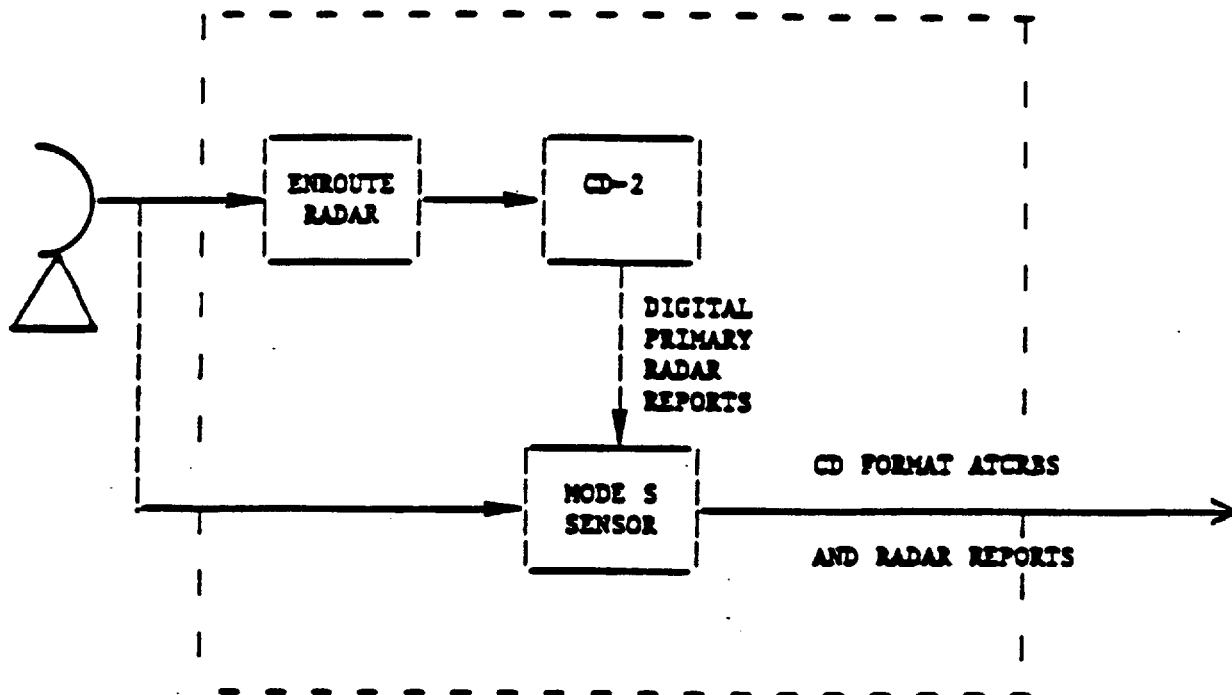


Fig. XI-3 Initial CD-2/Mode S Interface-With CD-2 Modification.